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STUDIES IN INDIAN SUGARCANES, No. 1
PUNJAB CANES

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PUNJAB CANES.

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INTRODUCTION.

THE multitude of varieties and complicated synonymy of the Indian sugarcanes, together with the frequent slight variations in the same cane in different localities, make a comprehensive study of these canes one of peculiar difficulty. It has been deemed advisable to commence with those of an isolated, more or less circumscribed area. The Punjab sugarcane tract is situated at the north-western end of the great submontane cane-growing area of North India extending from Assam and Bihar almost to Kashmir. In this tract large classes of canes are either ruled out by inclemency of climate or represented by solitary examples, the shortness of the period of growth and the incidence of frost being limiting factors. We have, thus, collected in the Punjab the smallest and hardiest canes in India. They would also appear to be among the most primitive in the world and show marked resemblances to some of the wild grasses of the genus *Saccharum* in the same region. The study of the Punjab canes has, then, this further interest that it is admissible to compare some of the most primitive canes with wild forms, in the hope of solving the interesting problem of the origin of the sugarcane, at present found wild in no part of the world.

The Gurdaspur District of the Punjab has had most attention paid to it because of the existence of a Government Farm there and a collection of varieties of sugarcane grown on it for the last two or three years. This has been a fortunate circumstance,

because it would appear that the two chief canes of this district, the *Katha* and *Dhaulu*, are the ones which most closely resemble *Saccharum spontaneum*, *Kahi* or *Kans grass*, in the general trend of the morphological characters which form the basis of this paper. With the inflorescence we shall have nothing to do, as it is extremely rare that these varieties flower, but the stems and foliage have received a very careful analysis. I am told that there is a local tradition that *Katha* has arisen from *Kahi*. This may be due either to the obvious likeness between the two or to the actual handing down through many generations of the story of the selection of some form of *Kahi* with enough sugar content to make it worth while to give it intensive cultivation. There is no doubt that *Saccharum spontaneum* (Tamil, *Kurivi Naanal*) responds very quickly to cultivation, and this has been demonstrated in the plants grown at Coimbatore. Furthermore, it is an interesting fact that, while *Dhaulu* and *Katha* are separable by a number of minute differences, the specimens of *S. spontaneum* thus far examined appear sometimes to take after one and sometimes after the other of these two varieties of cultivated cane. Thus the stems of the grass are sometimes red and sometimes yellow, sometimes as thick as *Katha* or extremely thin ; the plants may be prostrate or erect, the leaves narrow or broadish and the leaf sheaths spiny or smooth. The circlet of hairs is abundant or nearly absent ; the buds vary from densely hairy to almost glabrous, from small and low down on the joint, to elongated and very high up, and so forth. This variability of the wild form as contrasted with the rigid inheritance of minute characters by the cultivated types is not difficult to understand. While the former is regularly propagated by seed, and is widely distributed throughout the different climates and geographical tracts of India, the two typical Gurdaspur canes have probably been grown in this locality for many centuries, and have always, to all appearance, been reproduced from cuttings, thus securing the continuance of the special morphological characters of their first seedling parent. An almost exact analogy is met with in the wild and cultivated peppers of South India. From a detailed study of the many varie-

ties present in the pepper topes of the Wynaad, together with that of the whole of the wild forms of the Peninsula, it has been shown that many of the permanent types of cultivated pepper, such as *Balamcotta, Kallivalli, Cheriakodi,* have exact analogues in the examples of wild *Piper nigrum* collected on the Malabar Ghauts.[1] There is a common belief that the cultivated pepper has arisen from the wild or jungle pepper of this region, and, what is again striking, it has been shown that, for the production of seed, it is of prime importance that there should be an abundance of open anthers, a fact that is being made use of in the production of seedling canes at Coimbatore. Very few analyses have as yet been made of the juice of *Saccharum spontaneum,* but two seedlings raised from the same parent gave, on analysis, nearly three and nearly five per cent. of sucrose in the juice, besides varying greatly in habit and many other particulars. Two other facts may be mentioned as bearing upon the close relationship of the cultivated forms with *Saccharum spontaneum.* The two classes have been proved to be perfectly fertile *inter se* and numerous crosses have been raised with wild father and cultivated mother; and, secondly, among the seedlings of the indigenous Indian canes, there are occasional forms which would appear to "throw back" to such an extent that their similarity to *Saccharum spontaneum* is perfectly obvious. Seven such cases were met with in 180 seedlings of *Naanal* raised at Coimbatore in 1912-13, but it is not certain that the arrows of this cane were selfed.

The full study of the relationship of the Punjab canes with those of other parts of India has not yet been made, but it would appear that *Dhaulu* and *Katha,* themselves only differing in various small particulars, are connected with two series of canes gradually becoming thicker and more divergent as we arrive at better cane-growing conditions towards the south-east. Thus, related to *Katha,* we have *Lalri, Kansar, Chin* or *Chunnee, Baraukha* and *Saretha,* this series not apparently extending beyond the western

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1 Barber, C. A. "The Varieties of Cultivated Pepper." *Bull. III,* 56, *Department of Agriculture, Madras,* 1906.

parts of the United Provinces. From *Dhaulu of Gurdaspur* we have a much more extended series, commencing with the *Dhaulu of Ludhiana and Jullunder*, termed "*Dhaulu of Phillaur*" for convenience, and passing through *Dhaur*, *Bodi*, etc., to the great *Rheora* or *Mango* group, including many short thick canes typically present in Bihar. From certain morphological peculiarities it seems to me not impossible that this latter group forms a step between the indigenous canes of India and some of the thicker, cultivated, forms of the tropics, all traces of whose origin are at present, otherwise, lost in obscurity.

In these speculations it is however only right to point out that there are several tracts in India in which the desi[1] or indigenous canes have not as yet been studied. For instance, the solitary cane of the Central Provinces that I have seen, *Barhai* or *Barahi*, is obviously a cane closely related to *Katha*, which may have been brought down from the Punjab along the ordinary lines of migration. Then, there is the *Nargori* group of Bihar which, although evidently primitive, I cannot at present place. Less difficulty is likely to be experienced in regard to the occasional sporadic desi canes of South India, such as the *Naanal* of Madras and *Cheni* of Mysore. In no part of India which I have visited is the general facies of the canes of such a primitive character as in the Punjab, the smaller canes in other regions being rather the exception than the rule.

Sharply contrasted with the above hypothesis of the origin of the sugarcane in the part of India least suited to its growth, is the idea usually in vogue that the cultivated sugarcane arose from some wild form at the head of the Bay of Bengal, in Cochin-China or in the Malay Archipelago[2]. I am not in a position to discuss the latter regions, nor are there any detailed descriptions of the wild *Saccharums* there. But the absence of intermediate stages in Bengal between such possibly primitive canes and the thicker ones

[1] It has been found comparatively easy to separate the indigenous canes of any part of India from those introduced from the tropical islands. Canes which lie between these two classes do not come into consideration in this paper.

[2] De Candolle. *Origin of cultivated plants.*

in general cultivation there suggests that, if this were the place of origin, the change from wild to cultivated forms took place *per saltum*, a theory which requires a good deal more to be said for it than that of a gradual evolution. If, however, such canes were brought into being as would repay cultivation in *this* region, they would naturally creep along the base of the Himalayas in the submontane tract, where soil and moisture conditions would permit of the crop being grown without irrigation. But, the climate becoming constantly less suitable because of increasing cold and a shorter vegetative period, the canes would become uniformly smaller and more difficult to grow, until, in the Punjab, the limiting factor of moderately sharp frost would put a stop to further migration and the canes would reach the lowest grade. Now such a migration is actually taking place every year. It is certainly true of *Saretha* and *Kanara*, the latter cane, now found as far as Jullunder being, it is said, occasionally wiped out by frost and, after such a year as 1908, only slowly reintroduced. A similar case is presented by *Kahu*, a solitary representative of the *Ganna* canes of the *Pansahi* group which reaches its maximum in Bihar. By the long continuance of this interrupted migration we should ultimately get a series of frost-resistant or semi-frost-resistant canes of small size, exactly as we now meet them in the Gurdaspur District.

Enough detailed information of the distribution of the desi canes of India has not as yet been collected, to favour either of these hypotheses to the exclusion of the other, but it is interesting to keep the two points of view in mind and it is hoped that, as time goes on and more regions are submitted to a careful study, a larger mass of facts will render possible a choice between assuming that the Punjab canes are direct descendants of some such form as *Saccharum spontaneum* and have given rise to the better canes of India, and that they are degenerate members of groups evolved elsewhere.

Classes of canes met with in the Punjab.

The period during which I have been able to study the Punjab canes has unfortunately been short. It consists of three visits, between March 1913 and January 1914, to the Government Farm at Gurdaspur. A considerable number of canes have been collected there during the last few years, and these form the basis of the descriptions. It is pretty certain however that, as time goes on, other forms will be added, and the list of local canes increased. For instance, since my last visit, Mr. Southern has made the important discovery that the *Dhaulu of Gurdaspur* is not the cane grown under that name in the Jullunder and Ludhiana districts, and has sent samples of the latter to Coimbatore for examination. Any incompleteness of the list need not however deter one from describing those that have been examined, for, in order to detect such variations in the field, it is important that a full description of types should be at hand. The portion of the Punjab towards the United Provinces has not been at all fully explored and it is in this part that further varieties are likely to be found, but whether they are to be regarded as Punjab or United Provinces canes will depend on the opinion of the district agricultural officers. I have to record my appreciation of the great interest that Mr. Southern has taken in the purely morphological work which I have been attempting to do, and of his help in every possible direction. Through the kindness of Mr. Southern and Mr. Barnes, I have been able to place a certain amount of agricultural and chemical information in the first paragraph of the description of each cane. The paintings were mostly done on the spot by an artist lent by the authorities at Pusa, but a few were added by the artist of the Teaching Botanist at Coimbatore. The latter, whom I have trained myself, was also useful in making enlarged pen and ink sketches of my field drawings. I am responsible for the photographs. In

the latter the canes were placed on paper ruled with lines an inch apart, while, in the field, a bamboo is to be made out with a mark at about 6 feet from the ground.

The canes described in the present paper may be divided into the following classes :—

(1) *Katha, Lalri, Kansar.*—Thin to moderately thick canes with a brown colour largely diffused over the mature stems, heavily bloomed and therefore appearing pink or vinous or even violet, the brown skin showing strongly at the growth ring because of the absence of bloom there. These canes are closely allied to the *Chin* or *Chunnee, Lalri, Saretha* of the north-western portion of the United Provinces, but do not seem to have any relations further east. They are also represented in the Central Provinces by *Barhai* and doubtless others will be found in the elevated regions of the Deccan. The circlet of hairs at the node is strongly persistent in usually all the joints up the stem, the stems are cylindrical and straight, and the bud is small and rounded or pointed, reaching about the base of the growth ring.

(2) *Dhaulu and Tereru of Gurdaspur.*—Canes slightly thicker than *Katha* and differing from it in a series of minute characters. There is a comparative absence of the brown colour, suggesting a colour variety. The stems are glaucous green to clear bone yellow. The growth ring is marked, but of a light brown, and the circlet of hairs soon disappears entirely as we pass up the stem. *Dhaulu* in Gurdaspur district is grown on better land than *Katha* and is usually irrigated. I have at present met with no cane elsewhere belonging to this primitive class, but it appears to be related to the next.

(3) *Dhaulu of Phillaur.*—This cane shows sufficient resemblance to *Dhaulu of Gurdaspur* to warrant the suggestion that it has arisen from it. Thin, tall canes of a glaucous green colour, with zig-zag joints, a wide root zone and a very indefinite growth ring. The leaf scar is descending instead of horizontal as in *Katha* and *Dhaulu of Gurdaspur*, the circlet of hairs soon disappears under

the bud but is often traceable most of the way up at the back of the node. The bud is small and truncate, does not reach the growth ring and often only covers half the root zone. This cane appears to be almost identical with *Bodi* and *Dhaur* of the Meerut division and is an elongated, primitive form of the great *Mango* group of *Rheora*, *Hemja*, *Burli*, *Kuswar*, etc., of the United Provinces and Bihar. I have not met with canes of this class in other parts than those mentioned, and it probably does not extend into South India, but collections are at present incomplete.

(4) *Kanara of Jullunder*.—Bright green, soft canes much appreciated for chewing, often markedly oval in section, and apparently closely allied to, if not identical with, the *Kinar* of Meerut. Leaves very narrow. The circlet of hairs is constantly present and well developed. The bud is small and often squared, and does not reach the growth ring. The latter is well defined. It is interesting to note that this cane appears to be grown in conjunction with *Dhaulu* at Jullunder and, also, that *Dhaur-Kinar* is a constant mixture in Meerut. I am told that *Kanara* is occasionally completely wiped out by frost and that fresh seed has to be imported from across the Jumna. It seems reasonable to assume therefore that it is a migrated Meerut cane. I have not met with this cane, which is primitive in several respects, elsewhere than in the Meerut mixture, but there are many of the United Provinces canes still to be examined and it is too soon to speak of its further relationships.

(5) *Kahu*.—This cane stands by itself, in that it belongs to the *Ganna* class as contrasted with the *Ukh* canes thus far mentioned. A thick, juicy cane with protruding nodes and swollen root zones. The circlet of hairs persists only as a remnant of few long hairs under the bud. The joints are markedly zig-zag and have a well defined shape, which may be called ovate campanulate in the median view. The bud is large, ovate, pointed and extends beyond the growth ring, and there is frequently a cushion at its base. *Kahu* obviously belongs to the Pansahi class of canes, in which may be mentioned *Dikchan*, *Chynia*, *Yuba*, *Maneria* and *Lata*. It may be regarded as a migrant from the south-east.

Morphological characters used in the description of the Punjab canes.

The list of characters dealt with in the descriptions is professedly far from complete. It is the result of a steady evolution in the study of the cane during the past year and a half, but omits certain characters recently noted. As there appeared to be no previous work done in this direction, I have had to start from the beginning and, as a consequence, the distinguishing characters have fluctuated a good deal in value at different times. The earlier canes examined (in the March visit) are, on this account, very incompletely described in my notes and the greater part of the description depends on the visits of September 1913 and January 1914. And it is to be noted that, even now, the stability of the characters mentioned is by no means assured. I have, naturally, confined myself to characters which would appeal to a botanical morphologist, but am fully aware that there are whole classes of field and mill characters of systematic importance which I have been quite unable to touch. Accurate figures for tillering, hardness of rind and its detachability, quantity of fibre, and other characters at the mill, must be dealt with by officers constantly on the spot and in charge of the milling operations.

It was hoped that, by growing canes at Coimbatore, a useful series of specimens would be obtainable whereby to check the observations made in the Punjab. Unfortunately, it has transpired that it is nearly as difficult to grow the North Indian canes on the Coimbatore Cane-breeding Farm as it is to grow thick, tropical canes in the Punjab.[1] In the former case, moisture and its availability in the soil appear to be the limiting factors while, in the latter, frost and the length of the growing period determine the

[1] This difficulty appears, I am happy to state, to have been now overcome (November 1914).

character of the growth. The further fact that the land at Coimbatore is at present alkaline as regards sugarcane growing may turn out to be of use, when it is possible to examine the Northern canes grown there, in testing the stability of the somewhat minute morphological differences which form the basis of the descriptions. The conditions of the two localities could hardly differ more widely, and the past year has been one of pronounced drought at Coimbatore, under 16 inches of rain having fallen in the twelve months. The descriptions of the cane contained in this paper have this advantage, that the canes have all been grown at the same place (Gurdaspur Farm) under identical conditions and examined at the same time. I propose now to give a summary description of the characters observed as this will save a good deal of repetition and make the descriptions more easily understood. For illustrations of the characters I would refer to the drawings of the different canes.

List of characters dealt with.

1. General remarks as to distribution; agricultural, and chemical characters.
2. List of specimens examined.
3. General characters of the variety.
4. Cane measurements—
   - Dead leaves at six months old.
   - Length of cane and of shoot after stripping these.
   - Total length of cane and number of joints at six and ten months.
   - Total length divided by average thickness at middle.
   - Length of joints in different parts of the cane.
   - Thickness of the cane at various points.
5. Colour of Cane—
   - General.
   - Bloom.
   - Growth ring.
   - Root zone.
   - Blackening.
   - Blushing.
   - Scar line or band.
   - Ivory markings, splitting.
   - Groove markings.
6. Characters of the joint—
   - Thickness, ovalness in section.
   - Length of mature joint (deducting top), average longest, average shortest (basal).
   - Shape viewed medially.
   - Shape viewed laterally.
   - Leaf scar and its ending, Lip.
   - Circlet of hairs.
   - Groove.
   - Root zone.
   - Growth ring.

7. BUD—

Shooting, Bursting, etc.
Size and Form.
Origin and Cushion.
Flanges.
Bristles, Basal patches and Minute black hairs.

8. LEAFY SHOOT—

Colour.
Terminal tuft of leaves.
Character of leaf ends.
Number of terminal joints under 2″ long.

9. LEAF SHEATH—

Length; average longest.
Colouring, Bloom, Scarious border and edges.
Hairs on back and on edges.
Clasping stem.
Proportional width of sheath and lamina.
Ligular processes.
Ligule and hairs on its edge.

10. LAMINA—

Width and length, average extremes, and proportion of these to one another.
Channelling, etc.
Transverse marks.
Serrature.
Proportional width of midrib to lamina.

CHARACTERS DEALT WITH.

1. General remarks as to distribution and agricultural and chemical characters.

For this section I am indebted to Messrs. Southern and Barnes who have studied these aspects of the question on the spot. The section is capable of considerable enlargement. This is especially so in that I have come to the conclusion that there is no character of the sugarcane so stable as that which can be observed by a study of the field as a whole, the tillering, erectness, form of bunching, fall of leaves, angle of leaves to the stem, manner in which the ends of the leaves curve at different stages, blushing of the leaf sheath and stem on exposure, rooting and shooting, and any other marked peculiarity of growth—such are characters which can only be noted after a longer field study than has been possible.

2. List of specimens examined.

This I have considered to be necessary, because it may well be that canes of the same name, found in fresh localities, will differ in some particulars. Such varieties will be of considerable interest as, thereby, we may be able to make a better chain of evolution, such as that hinted at in the Introduction, and will be of obvious use in testing the validity of the theories advanced regarding the origin of the sugarcane.

3. General characters of the variety.

This is intended to form a summary of the cane characters for general use. For instance, it may be of value in any doubtful case where an officer is touring and has not the opportunity of making a detailed study.

4. Cane measurements.

The subject of cane measurements is at present in a state of flux, as it has not been possible to determine how many canes should be examined in each case to obtain a fair average. Obviously, it is highly important that the specimens should be selected with great care, and the method adopted has been to take average mature canes from various parts throughout the field. The measurements taken during the September visit were confined to six cane shoots. This number will probably turn out to be insufficient. In January, 20 canes were measured and it is hoped that this number will prove ample, for the labour is excessive, not only in making the actual observations but in working out the averages. As will be seen from the note attached, these measurements of 20 canes have brought out some interesting facts. As regards the length of the joints in different parts of the cane, the canes in the field may be divided into two classes, and it is possible that this will ultimately be extended to the measurements recorded of other parts. The following are the numbers and measurements at present considered to be of varietal importance:—

(1) *Number of dead leaves at six months old.*

(2) *Length of cane and shoot after stripping these.*—These combined should, it is anticipated, give some criteria as to the rate of growth and rapidity of maturing of the different canes. It is seen that the more typically indigenous forms of the Punjab mature much more rapidly than such as appear to have been introduced from further east, where the conditions of growth are more favourable in a longer growing season.

(3) *Total length of cane at six and ten months* after stripping all the leaves, and the *number of the joints* in each case.

One of the most surprising features brought out by these measurements is the small growth in length and few joints added after, say, September. The canes are, to all intents and purposes, fully formed in this month.

(4) *Total length of cane divided by average thickness at middle, $l \div t$.*—It is hoped that the figure thus obtained will serve as a sort of index to the character of the cane. The tall thin canes characteristic of the Punjab will, presumably, have a very different figure from the thicker introduced ones. Thus *Katha, Dhaulu of Gurdaspur* and *Tereru* have index figures 156, 142 and 150, respectively; *Kansar* has 109; *Lalri* 81, *Kanara* 85, *Kahu* (thicker *Ganna* cane) 74; *Dhaulu of Phillaur* (an elongated *Rheora*-like cane) 97.

(5) *Length of Joints in different parts.*—At six months, only six canes were measured, but 20 were measured at ten months, when the cane was practically mature and growth had ceased. The curves obtained for these measurements have, as already mentioned, led to interesting results which will be further elaborated in a special note below.

(6) *Thickness of the cane at various points.*—The method finally adopted has been to measure the lowest joint, the middle one and the uppermost mature one. Sufficient numbers have not as yet been accumulated to draw any general conclusion, but it is probable that useful differentiating characters may ultimately be obtained from these measurements. The Punjab canes are, generally, characterised by considerable uniformity all the way up.

5. Colour of cane.

This has always been recognised as an important differential character in canes. In fact, all previous classifications, with which I am acquainted, use colour, whether green or yellow, red, ash-coloured, striped, etc., for the main divisions. That this is unsatisfactory is at once seen from the fact that the same stool has been seen with green, red and striped canes on it.[1] Furthermore, the colour of a cane changes very rapidly under different conditions, the *Kaludai Boothan*, a glaucous yellow cane of Coimbatore, developing a fine claret in Pusa. But colour is, none the less, an important character, and the canes grown long in any

[1] Barber, C. A. "The Origin of New Sugarcanes by 'Bud Variation.'" *Agricultural Journal of India*, Vol. I, Part IV, October, 1906.

locality assume quite definite tints which are of use in rapidly separating them at the mill. Thus the *Dhaulu of Phillaur* was at once distinguished in the *Kanara* plot in Gurdaspur Farm in January last, the canes being glaucous green instead of full green, and this led to the interesting discovery reported above that the *Dhaulu of Gurdaspur* is an entirely different cane from the *Dhaulu* grown further east in the Punjab. Colour is therefore always carefully noted.

Bloom is the layer of waxy hairs or scales which is met with in most canes, best developed at the top of the joints and there called the *bloom band*, but descending over the joint to a greater or less degree and influencing the general colour of the stem. Thus, when the skin is green the bloom renders it glaucous green, when the skin is brown the canes become tinged with a vinous or violet colour according to the relative strength of colour and bloom; a green stem without bloom gives a grass-green cane and so on.

The colour of the growth ring and root zone (see below) are also often characteristic. The former is rarely bloomed and thus usually stands out as a marked layer, especially in the canes of the *Katha* alliance where the skin becomes brown at maturity. The root zone is often bloomed and, usually yellow in these canes, becomes cream coloured.

Blackening, as if a layer of soot were spread over the joint, is due to the growth of a superficial fungus on the bloom (kindly examined for me by Mr. McRae, the Madras Government Mycologist). This discoloration occurs chiefly at the upper parts of the joint where the bloom is thickest. Incipient blackening often obscures the normal cane coloration.

Blushing is shown where the canes are tinged on exposure, *e.g.*, where the leaf sheaths separate and one side of the joint is visible. The Punjab canes differ a good deal in this character, those of the *Katha* alliance hardly showing any change, while the *Dhaulu* section are readily tinged with red or violet. This leads to a curious paradox. The *Katha* canes are glaucous green at six months old but various shades of brown or violet when mature,

in fact the *Katha* cane is classified as a "red" cane. And yet, at six months, the *Dhaulu* is a "red" cane because of blushing violet and the *Katha* green because it does not blush. There is another form of coloration which has been insufficiently studied, namely, the tinge taken on by canes after being cut. *Dhaulu*, and especially *Kanara*, are seen, after a day or two, to be of brilliant pink red, while there is little change in *Katha*. What relation this change of colour in the cut cane has to blushing in the field is not quite clear, for I find that I have not noted blushing in *Kanara* in the field, although *Dhaulu* readily turns violet.

Scar band and scar line.—These marks are somewhat difficult to describe, but in certain canes a sharp, dark-brown line is seen immediately under the scar left by the fallen leaves. This line is above the bloom band. In others no definite *line* is seen, but a broader, less defined, greyish or brownish *band*, so that the bloom layer does not reach the leaf scar at the top of the joint. This is one of the differences between *Dhaulu of Gurdaspur* and *Katha* and would appear to have some connection with the circlet of hairs (see below) which is strongly present in the latter and very soon disappears in the former. In some examples the scar band is seen to be rough with minute hairs, or at any rate puberulous, and it may be that this roughness interferes with the deposit of bloom at this place.

Ivory markings.—This is the name given to the thin dark lines seen on the joints of so many canes. Although variable under different conditions, they are undoubtedly of diagnostic value. Sections through the epidermis show that these lines are in reality small splits and they are frequently accompanied by the formation of large, thick-walled cells below, as if placed there to prevent the deepening of the split or the entrance of fungus spores. The term has been used because of the resemblance of these lines to the markings on old ivory, but it is not very satisfactory. The ivory markings are often seen, in the Punjab canes, to give rise to visible splits in the rind, especially in the younger upper joints, and such

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splits differ from the larger, deeper ones of other canes. The ivory markings differ as to their position on the joint. There are two main classes of arrangement in the Punjab canes. In some canes, such as *Dhaulu* of *Gurdaspur* and *Tereru*, the markings are chiefly confined to the middle of the joint and do not cross the bloom band; in others, *Katha* and *Dhaulu of Phillaur*, they are commonest in the upper part of the joint and frequently cross the bloom band as small splits. In a good many canes they are present on the root zone, especially in lower, older joints. Not uncommonly ivory markings appear on a certain upper young joint in quantity, although hardly present elsewhere on the cane, and it is surprising how uniformly this occurs in the different canes of a plot. The significance of this is not understood. Cases have been noted where a cane without ivory markings in its normal habitat becomes covered by them when grown in another place, thus detracting from their value as a morphological character, and this is partly the reason why I have taken *Dhaulu of Gurdaspur* and *Tereru* to be really the same variety under different conditions.

The Groove markings (see below) are sometimes of peculiar character. The groove would seem to hold a position within the leaf-sheath to which minute organisms find easy access, but the causes of markings there have still to be worked out. A very common marking is a series of minute rounded bodies, brown at first but ultimately forming a harsh, black incrustation. It may be that these bodies are due to punctures by mites, but this point has not proved easy of determination. They are markedly present on many samples of *Saccharum spontaneum* (*Kahi*, *Kans grass*). Another marking is of a red brown colour and, under the lens, is seen to consist of a series of fine parallel lines of a brown red colour. And it is a curious circumstance that these red marks are not found in canes of the *Dhaulu* alliance while they are constantly present in all *Katha* canes. No idea has been formed as to their cause.

6. Characters of the joint.

I have found it convenient to make this popular term equivalent to the Botanical term "internode," the portion of the stem

between two leaf-scars. It is never used as meaning the node, but includes the bud with the portion of stem above it as far as the next leaf-scar.

Thickness, Ovalness.—The thickness of the cane has already been partially dealt with. But the measurements taken for the cane in general only deal with the comparative thickness in different parts, in fact the shape of the cane as a whole. In the earlier observations the joint itself was measured by calipers at various points, to wit, the leaf-scar, the root zone, the growth ring and the middle and top of the joint. But this has now been largely given up and, instead, the thickness has been taken in the middle of the joint in two directions at right angles to one another. Such measurements have demonstrated that the stem of the sugarcane is constantly oval in section, being narrower from side to side (laterally) than from back to front (medially). This is doubtless caused by the form of the shoot and the distichous arrangement of the leaves. But this slight ovalness can be ignored when comparing such canes as *Kanara* and *Katha* for, in the former, it can be seen at a glance that the cane is oval, whereas in the latter it requires the careful measurements by calipers before this can be determined. *Ovalness* therefore means, in the descriptions, such marked difference in the two measurements as can be readily detected by the eye. Canes of the same variety vary sometimes a good deal in the thickness of the joints in different parts and, as an index of thickness, the middle of the cane has been chosen. At least twenty canes have been measured, excepting in the earlier examinations. Ovalness is often noted as especially marked at the base of otherwise cylindrical canes and, more frequently still, in young swollen joints at the top. Such characters are detailed where observed, and it is seen that varieties differ a good deal with regard to them.

Length of mature joint; average longest and average shortest (basal).—This is not easy to formulate, because it is difficult to determine in each case where the mature joints end. For the purpose of this paper, joints at the top, under two inches in length, have been ruled out as immature, while all the basal joints have

been included. The results are thus the averages of fifteen to twenty joints of twenty canes, some four hundred joints, and it is hoped that this method will bring out the differences which undoubtedly occur in cane varieties. Canes vary much in thickness and length of joint under different growth conditions, but the figures given in this paper refer to canes grown in the same place and under the same field conditions, with the solitary exception of the *Dhaulu of Phillaur* discovered after the last visit to the Punjab.

Shape viewed medially.—This does not need much explanation. The point of view is with the bud in front, and this is termed the front of the joint, the other side, where the bud is absent, is termed the back. The thinner canes of Gurdaspur are generally long jointed and do not differ so much in the matter of shape as thicker ones, like *Kahu* or *Kanara*. And this fact will help ultimately to distinguish them from the canes of other parts of India.

Shape viewed laterally, that is with the buds in two series right and left. There are characteristic thickenings in the joints of the sugarcane which are often very slightly developed in the Punjab canes. *Kahu* is an example of a cane with such thickenings well shown, and the relative development in different parts of the joint helps to distinguish the different canes.

Leaf-scar and ending, Lip.—The leaf, when falling, does not come absolutely clear away, but leaves a narrow ridge behind. This is termed the *leaf-scar*, and is seen to be either horizontal, when viewed from the side, or descending towards the bud, and this difference is of considerable importance in cane classification. *Dhaulu of Phillaur* is, for instance, at once distinguished from *Dhaulu of Gurdaspur* by this character, the former having markedly descending leaf-scars which are horizontal in the latter. Sometimes a larger piece of the leaf-scar remains under the bud and this is termed the *lip*. The lip is not usually developed in the Punjab canes but forms a very marked feature in many others. The *ending* of the leaf-scar, being the outer end of the enveloping leaf-sheath, is some-

times marked. It is not usually met with in the Punjab canes except in *Kahu* but sufficed at once to separate *Sonabile* at Gurdaspur, and thus to discover the wrong naming of a cane called *Matna* on the Farm. In the cane mentioned (*Sonabile*), it is markedly decurrent and dark in colour, forming a sharp line as if drawn by a pencil across the leaf-scar at the side. It is, therefore, included in the general description of the cane.

Circlet of hairs.—I have been led to lay great stress upon the presence or absence of these hairs. If a young side shoot of the cane is carefully examined, it is seen that, when the leaves are torn off, a layer of close, parallel, fine, silky hairs is present at each node, the hairs arising immediately below the leaf-scar. When, however, a thick tropical cane is examined these hairs are rarely observable, although occasionally a few may be met with in the basal joints. Many of the indigenous Indian canes have these hairs very well developed right up the stem, and their presence seems to me to indicate a primitive stage in development. Their occurrence is probably a "youth character" from their constant presence on the young side shoots. But the Indian canes vary much in the relative persistence of the circlet of hairs. In *Katha* and its allies and in *Kanara* they are seen all the way up the stem, while in *Dhaulu of Gurdaspur* they soon disappear as we proceed upwards. In *Dhaulu of Phillaur* they disappear at a very early stage from under the bud, but are often traceable all the way up at the back of the node. In *Kahu*, on the other hand, they are only preserved as a few stiff long hairs under the bud. These differences are found to be fairly constant in any variety or indeed class, the circlet of hairs is always studied, and I have come to regard its relative persistence as a very important factor in classification. Such circlets or collars of hairs are often met with in grasses, and the wild *Saccharums* differ a good deal among themselves. Observations on the circlet of hairs may turn out of considerable value in tracing the origin of cultivated canes.

Groove.—This is the depression on the stem at the base of which the bud lies. It varies a good deal in different varieties and is

poorly developed in the indigenous Punjab canes. In some canes it is very strongly developed.

Root zone.—This is the region at the base of the joint whence the roots arise in germinating canes. The incipient or resting root tips are seen as clear round dots, and are often arranged in regular rows one above another, the lowest always being the largest and often the first to emerge. The width of this zone varies a good deal in different varieties, *Dhaulu of Phillaur* showing its likeness to the *Rheora* group by having a very broad root zone. The shape also is often characteristic, in that the thinner Punjab canes generally have flat root zones, even becoming thinner downwards, while *Kanara* and especially *Kahu* have protruding zones thickening bell-like downwards. The number, size and arrangement of the dots or eyes also vary a good deal. In *Saccharum arundinaceum* there is a single row of widely separated root eyes, in *Saccharum spontaneum* we have two or three moderately distinct rows as in the case of *Katha* and *Dhaulu of Gurdaspur*.

In *Dhaulu of Phillaur* the eyes are two to three deep, but it is often difficult to arrange them in rows, the lower ones being much larger and more distinct. The root eyes in *Namalu* and its allies in South India are very numerous and minute, as many as six or seven rows being sometimes seen. They also vary greatly in distinctness in different varieties.

Growth ring.—This is the representative of that zone, often swollen, in grasses by whose activity fallen shoots raise themselves, a zone of permanently active tissue where rapid growth may take place on either side of the stem, a zone of intercalary meristem. That this function is performed in the cane can be seen in almost any field of *Katha*, *Dhaulu* or *Saretha*, and in many other varieties, for, wherever the cane is curving, the growth rings are wider, and especially so on the lower side of the stem. But I have met with a number of cases where the growth ring does not appear to be very active, especially in the thicker canes of South India. Here severe curvatures of the stem are sometimes due to a direct bending

of the stem above the growth ring. The growth ring is situated immediately above the root zone, at the base of the joint. It is usually devoid of bloom (although waxy scales are sometimes seen on it), even when the root zone is covered, and is thus frequently marked out by its colour, as in *Katha, Chin, Saretha, Kansar,* &c. In North Indian canes it usually has definite upper and lower boundaries, but in *Dhaulu of Phillaur*, it is often difficult to see it at all. This is even more so with *Rheora* and its allies, and in this respect they agree with most of the thick canes of the tropics.

The growth ring is thus of considerable importance in classification, and its study has led to the suggestion that, if the tropical canes are derived from indigenous Indian ones, it may be along the line of the shorter, thicker, broader-leafed *Rheora* group.

7. Bud.

From a study of these in many canes, I have been led to lay high value on the character of the bud in classification. This is not to be wondered at when it is considered that the bud contains the characters of the shoot in embryo. I have had to invent various terms for the different parts, some of which may not be well chosen, but there has not at present been time for a thorough morphological study of the bud. The size, form, point of origin and vestiture are the chief ways in which the buds of different varieties may be distinguished.

Shooting, Bursting.—The cause of the shooting or emergence of the buds has not been properly studied at present. That it may have something to do with free percolation of moisture is suggested by the enormous development of this character in canes sent from Samalkota to Pusa, where unaccustomed ease was doubtless experienced by the roots in obtaining the water in the soil. But different canes vary much in the amount of shooting and, some of them in the place where shooting takes place normally. Observations on this phenomenon have not at present been possible in the canes described in this paper, and the matter has to be much more

carefully studied before any conclusion can be arrived at as to the permanence of the character under different conditions.

Bursting is the term applied to the point at which the apex of the bud emerges. For determining this it is not necessary for the apex to have shot out, for the arrangement of the bud scales and their venation in the resting condition will give the necessary indications. As a general rule, elongated buds burst apically, whereas rounded or truncated buds emerge from the middle of the back, or dorsally. There are all stages between these two and the character of bursting is usually more or less constant, although the upper younger joints have more elongated buds, with the corresponding change in the point of emergence.

Size, Form, etc.—Here, again, we meet with great diversity among cane varieties, whether Indian or tropical. The buds of *Katha* and *Dhaulu of Gurdaspur* are rather small, but they cover the root zone and extend upwards to the growth ring. In *Dhaulu of Phillaur*, on the other hand, they are usually truncate and do not nearly reach the growth ring because of the broad root zone. In *Kahu* they are very large and pointed and extend beyond the growth ring in most joints, while in *Kanara* they are rounded or squared and do not reach the growth ring, although the root zone is not broad. In *Pooran*, a thick South Indian cane, they are very small and rounded while in *Kaludai Boothan* they are broad and large. These and other characters of the buds are usually fairly constant for the variety and it is one of the most convenient characters by which to determine doubtful canes at the mill.

Origin and Cushion.—The buds are protected by the base of the leaf, termed the leaf-sheath, and in the growing shoots are completely hidden from the outside world. When the leaves are stripped, it is seen that the buds are usually placed immediately above the leaf-scar and often partly covered by it. In other cases, however, as in *Kahu* and some upper joints of *Dhaulu of Gurdaspur*, they arise at some little distance above the leaf-scar. When this

occurs there is sometimes a small area between the bud and the leaf-scar, more or less sharply marked off by two downward curving lines, which is devoid of hairs or root eyes. This is termed the *cushion*, and it is typically developed in the *Pansahi* group of which *Kahu* is a member.

Flanges.—The two opposing lowest bracts or bud scales generally have, on either side, scarious borders which are termed flanges. These vary a good deal in different varieties. Their point of origin varies. In the elongated buds they often arise low down and in the circular or truncated buds they usually arise above the middle. They are continued, as a frequently dark-coloured margin, round the apex of the bud and are there either pointed, rounded, truncated or even emarginate, modifying the shape of the bud in this direction. In *Namalu*, a thick Coimbatore cane, they are produced into a long beaked process beyond the apex, in *Kaludai Boothan* they are very broad at the sides and often auricled, while in *White Mauritius* they are developed into two broad scarious wings which are very characteristic.

Bristles, Basal patches, and Minute black hairs.—The vestiture of the bud is of considerable interest, although the exact homology of the different forms of hairs has not yet been worked out. The flanges are more or less coated with stiff, long, straight hairs, often projecting to a considerable distance beyond the apex of the bud. These are called *Bristles*. Sometimes there is a marked tuft at the base of the flange, at other times the bristles are confined to the inner sides or to the edges.

The sides of the bud below the origin of the flanges have hairs of another kind. These, when typically developed, are arranged in parallel lines and strongly recall the circlet of hairs, with which they are perhaps homologous. They are often white in colour and more or less crisped, very delicate and closely pressed to the sides of the bud. Their general direction is that of the nerves on the scales and they not infrequently merge into a series of hairs on the veins. Sometimes they are continuous, on the other hand,

with the bristles of the flange or the tuft of these at its base. In many varieties these *Basal patches* are poorly developed or even absent and sometimes their place is taken by a puberulousness or by minute black hairs.

Minute black hairs are common on the bud in many varieties. They appear to be always present on *Dhaulu of Gurdaspur*, while hardly ever observable on *Katha*. They are usually most developed on the veins of the bud scales, at the apex of the bud or in the region of the basal patches, but they may also occur at any part of the bud. Such minute black hairs are a constant feature of the base of the leaf-sheath, between the veins, and are not infrequently found in the scar band, making it more dusky in colour.

8. Leafy shoot.

Observations on this part of the cane have not been properly worked out. The colour, the arrangement of the leaves along the stem, the character of the leaf tip, the manner of clustering at the end and other characters of the shoot, can only be studied in plants in full vigour, and the opportunity has not yet occurred for doing this thoroughly. The bunch of leaves at the end of the shoot is usually described under the term *terminal tuft*. I have included in this the number of visible leaves arising on the last 2″ of the shoot. The number of leaves in the terminal tuft is largely dependent on the rate of shortening of the end joints in the cane, because one leaf is borne at each node. Accordingly, the lengths of the end joints of the cane are entered here, down to one-tenth of an inch, beyond which it has not been found safe to go. There is no doubt that canes vary much in the number of leaves in the terminal tuft, but a study of the figures obtained from the canes six and ten months old has made me cautious as to generalising. Taking the number of joints to be passed from the apex before a two-inch length is reached, it is easy to see that there are a great many more in the older canes. In other words, the rate of growth in length of the cane is greatly diminished.

9. Leaf-sheath.

It is surprising how many characters of classificatory importance can be drawn from a study of the leaf-sheath. This part is homologous with the bud scales and there too we saw that quite a number of characters could be made out with careful observation. Some of the characters mentioned below have not been fully studied but they are mentioned in the belief that they will ultimately prove useful.

Length, average longest.—The length of the leaf-sheath, or lower sheathing portion of the leaf, varies a good deal in different varieties. Thus, the sheath in *Kahu* and its allies is short, rarely exceeding 10—11 inches, while that of the *Rheora* group reaches or even exceeds 15 inches. The average length of the sheath has been taken of the six canes examined at Gurdaspur six months old. It is not possible to do this much later, as the older ones rapidly become broken. But this method has the disadvantage that the growing period has not ceased and, while it lasts, there seems to be a constant tendency towards the increase in length both of sheath and lamina. The average longest is therefore added to the figures.

Colouring, Bloom, Scarious border and edges.—The colouring of the leaf-sheath has not been very uniformly noted in the varieties. But the *Kahu* group show characteristic purple blotches, possibly due to a special fungus invasion. The fact that certain varieties of canes are attacked by special fungus or insect pests is constantly borne in on one, and there is a mass of work to be done in this direction because such attacks are of obvious classificatory value. The markings, lines, blotches on the leaf-sheath are probably a case in point. Bloom is often present on the leaf-sheath, but not always, and *Katha* and *Dhaulu of Gurdaspur* differ in this respect. When the sheath is mature and commences to dry up, this usually happens along the edges first. There is frequently a discontinuation between the lamina and leaf-sheath at the point of junction, the leaf-sheath being wider ; and thus the decay of the edges of the leaf-sheath is probably connected with disuse in no longer passing up water

to the lamina or with decay for lack of nutriment passing downwards. The different kinds of sugarcane differ remarkably in the early appearance of this dried up, *scarious border* and, although it is most often found in the thicker tropical canes, it is always well to note it. The *edges*, lastly, of the young leaf-sheath sometimes assume definite colour. In *Dhaulu* the edges soon become red brown while in the *Katha* family they are more or less light coloured and transparent.

Hairs on back and on edge.—This includes, generally, the vestiture of the leaf-sheath, the inside being smooth and shining. Many of the sheaths are well armed with silicious spines variously distributed over the back; all have minute hairs between the veins behind, so minute in most cases that they are a mere puberulousness, and these hairs are usually black below and white in the upper part of the sheath. There are tufts of long silky hairs on each side where the sheath joins the lamina. The development of these varies a good deal and they sometimes extend down the edge of the sheath for some distance. Besides this vestiture there are various kinds of roughnesses which have not been studied in the Punjab canes.

Clasping stem.—This refers to the base of the leaf-sheath, where it is fixed to the stem. It is sometimes very wide, as in *Katha,* where it clasps the stem for one and a half times its circumference; in *Dhaulu,* on the other hand, it is proportionately narrower and clasps the stem only for one and a quarter times its circumference. This is seen in the plates of these two canes.

Proportional width of sheath and lamina at the point of junction, Ligular processes.—The relative width of lamina and sheath has been found to be of some importance in diagnosis. It is connected with the scarious border referred to above, but more especially with the ligular processes. As stated above, the sheath is usually wider than the lamina. If this excess is greater than 25 per cent. there is usually an extension upwards of the sheath as a

separate outgrowth. This is called the *Ligular process*, and often occurs on one side only, namely, the inner. The presence or absence of ligular processes, depending as it does on relative width of sheath and lamina, is a very useful character, and serves almost of itself to divide the Indian canes into sections. Thus, in the *Pansahi* group ligular processes rarely occur, whereas they are constantly present in the *Katha-Chin* group. *Dhaulu of Gurdaspur* may be distinguished from *Katha* by the absence of the ligular process, and so forth. Sometimes the processes attain a very large size and are very striking features on the shoot. A recent seedling at Coimbatore has ligular processes over $6\frac{1}{2}$ inches long. As to their exact morphological value, after careful examination, I have come to the conclusion that they may equally well be called "ligular" and "stipular" but, because of the comparative absence of the latter organs in the Monocotyledons, and the fact that they are in direct continuation laterally with the ligules, I have adopted the former term. They may, for the present, be considered as lateral expansion of the ligule. Thus they have nothing to do with the outgrowths of *Oryza*, *Hordeum*, etc., which are expansions of the base of the lamina, but are practically equivalent to the ligular expansions in *Ammophila arundinacea*, with the middle part remaining short while the two sides have grown out, and are provided with fibrovascular bundles as in that case.

Ligule, and hairs on its edge.—The ligule is the small scale-like outgrowth on the ventral side, where the leaf-sheath and lamina unite—a constant feature of grass leaves. This varies a good deal in its shape and development in the different varieties of canes but lack of time has prevented its careful study thus far. Both its upper and lower margins are capable of considerable variations in outline and, in general, it frequently has a lozenge-shaped wider portion between extremely narrow wings. The edges are clothed with a delicate fringe of setæ, and these again vary a good deal. They are usually small and closely arranged, but in *Sonabile* they are long and ciliate, while in the *Kahu* group they are poorly developed and frequently disappear early.

10. Lamina.

This part of the cane has at present been incompletely studied and several characters, since noted, have not been noted in the Punjab canes. The leaves of the North Indian canes dry up quickly towards the end of the season. Those at Aligarh hardly had a trace of green in them in January because of the dryness of this region, while those at Gurdaspur were yellow or straw coloured at the same time because of frost. As it was found impossible to make comparative observations on the foliage at this time of year, a special visit was paid to North India during the last rainy season and the characters here detailed are the result of that visit.

Width and length, average extremes, and proportion of these to one another.—The width of the leaf in any variety or in any shoot of any variety is not constant. Well grown specimens will have a vastly different width of leaves from that in a meagre half starved plant. And in the same bush the leaves vary a good deal according to age, the period of growth and the activity of growth at any time. This renders the comparison of the width of leaves difficult and I have merely taken what appeared to me the general width and added to it the maximum observed. The same remarks apply to the length of the lamina, except that this has been carefully measured in six shoots, to determine the form of curve presented by the increasing length of leaves from the base, and also to see if any relation could be traced between length of leaf and of sheath and thickness of joint. The figures taken have not yet been studied in these directions and are probably too few for any deductions to be made. Besides this, there was great difficulty in measuring the length of the lamina because the tips were so frequently injured and the lower leaves broken off, and numerous approximations had to be made. For these and other reasons, I have elected to take the extreme length and width for each case and, by dividing the former by the latter, have tried to get an index for the leaf, in exactly the same way as was done for the stem. A reference to the

figures will show that the leaves of the Punjab canes are as a rule very narrow, rarely much exceeding one inch, and in *Katha*, as might be expected, falling a good deal short of this. *Kahu* stands out with a width of over 2 inches, a representative of the broader-leafed *Ganna* canes. The index figures range from 59 for *Katha* to 23 for *Kahu*, chiefly due to differences in width, as there is no very great variation in the length of the leaf in the Punjab varieties.

Channelling, etc.—This refers to the way in which the base of the lamina is folded. In *Katha* it forms a well defined channel at the base, and this is constantly less evident as we proceed to the thicker canes. In *Saccharum spontaneum* the channelling is a marked character. Under this heading might be included the character of the leaf edges, they being sometimes straight, sometimes wavy, or indeed twisted at the base. The vestiture has not been studied in these canes but there are many points in it worthy of note. This may be referred to in later descriptions.

Colour and transverse marks.—Here, again, observations are incomplete. The colour of the leaf is often an index to the health of the plant, deep green being the sign of abundant nitrogenous assimilation. But there are also varietal differences. For instance, the leaves of *Katha* are more or less grey green or glaucous green and rather dark, whereas those of *Dhaulu* are of a much fresher green with less bloom. The transverse marks are seen dorsally at the base of the lamina on each side of the midrib. The lamina at this place is not infrequently bloomed and more or less devoid of the green colour of the leaf elsewhere. Sometimes there are patches of colour, purples, browns, pinks predominating, but the North Indian canes do not show many of these more striking colorations and have not attracted much attention as a consequence.

Serrature of the edge of the leaf.—As is only too well known, the edge of the cane leaf is provided with a series of close-set, silicious spines, all facing one way and capable of acting like an exceedingly sharp saw and causing severe cuts on the face and hands. An

attempt was made to study this feature, but the work came to a practical standstill by the discovery that, in any one leaf, the form and arrangement of the spines varies with the part of the leaf in which the observation was made. It has now been decided to examine the hairs at the middle of the leaf only. Care must be taken to select a leaf from which the spines have not been broken, as they are sometimes very fragile and the youngest unfolded leaf is often found to be most suitable. If still younger leaves are taken the hairs are undeveloped. There is no doubt that the harshness and persistence of the spiny hairs on the edges of the leaves of canes vary a great deal in the different varieties, and the matter will be worked at until some useful method can be evolved of putting these differences down.

Proportional width of lamina and midrib.—This has at present been incompletely studied. It is evident that narrow-leafed canes such as *Katha* differ very widely from the others in the relative width of the midrib and the lamina, and the North Indian canes as a whole differ almost as much from the thick tropical canes met with further south. The plan adopted has been to take the proportional width of midrib to that of the whole lamina, at the base, and at distances of one inch, 6 inches, 12 inches and at the widest part of the lamina wherever that may be. These observations have hardly been commenced, and it is proper to state that the measurements of foliage of the sugarcane generally are only here mentioned in order to indicate the lines on which it is proposed to work.

For convenient reference, a summary of the measurements of the varieties dealt with in this paper is appended (Table I).

TABLE I.—*Summary of Measurements of Punjab Canes.*

	No. of dead leaves.	Length of canes after stripping these.	Length of Shoot.	Total length of cane at 6 months.	Total length of cane at 10 months.	No. of joints at 6 months.	No. of joints at 10 months.	No. of few-jointed canes in 20 canes at 10 months.	Average length of mature joints at 10 months.	Average thickness at middle of mature joints at 10 months.	Index of cane. Length divided by thickness.	Average shortest (basal) joints at 10 months.	Average longest joints at 10 months.	No. of joints under 2″ long at apex—6 months.	No. of joints under 2″ long at apex—10 months.	Average greatest length of leaf-sheath.	Proportional width of lamina to sheath (100) at junction.	Average extreme length of lamina.	Extreme width of lamina.	Extreme length of lamina divided by extreme width.	Proportional width of mid-rib to lamina (100) at 1″ from base.
Katha	14	4′1″	5′6″	57″	62″	22	23	7	3·7″	0·40	156	2·0″	5·3″	3	6	11·3″	71	3′11″	0·8″	59	33
Lalri	12	3′3″	4′1″	52″	50″	19	17	10	3·3″	0·55	91	1·6″	4·6″	3	5	11·7″	78	4′4″	1·05″	50	20
Kansar	7	2′7″	7′9″	64″	65″	18	20	10	4·5″	0·59	109	2·5″	6·0″	4	6	12·8″	72	4′4″	1·13″	40	..
Dhaulu of Gurdaspur	14	4′9″	5′9″	73″	69″	25	27	6 ?	3·1″	0·49	142	1·7″	4·5″	5	7	10·9″	82	4′0″	1·30″	37	18
Tereru of Gurdaspur	13	3′3″	6′7″	66″	71″	24	24	12 ?	3·7″	0·45	150	3·1″	4·8″	4	6	10·2″	..	3′9″	1·20″	37	..
Dhaulu of Phillaur ..	..	..	..	..	59″	..	23	..	3·6″	0·61	97	1·6″	5·6″	..	8	..	..	..	..	..	..
Kanara	10	2′4″	6′3″	50″	54″	21	25	4	2·6″	0·61	85	1·1″	3·8″	3	7	12·0″	76	3′10″	1·0″	46	..
Kahu	10	2′4″	6′4″	47″	57″	18	21	10	3·7″	0·77	74	2·7″	4·7″	4	6	10·3″	84	4′2″	2·2″	23	14

Note on the length of joint in different parts of the sugarcane.

The measurements of length of joint given in this paper are averages, in each variety, of six canes six months old and twenty ten months old. They were taken from the same plots at Gurdaspur Farm in September and January, with the solitary exception of *Dhaulu* where they were taken from different plots. It is unfortunate that only six canes were measured in the first period, but this was due to the fact that the real work of that visit was the study of foliage characters and more than six canes could not be dealt with in the time at disposal. The number of canes necessary for a proper average of each quantitative character has not as yet been determined. While it is certain that six are not enough for relative length of joints, it is hoped that twenty may be ample, because the labour, as explained above, is excessive, not only in taking the measurements and tabulating them but in working out the averages.[1]

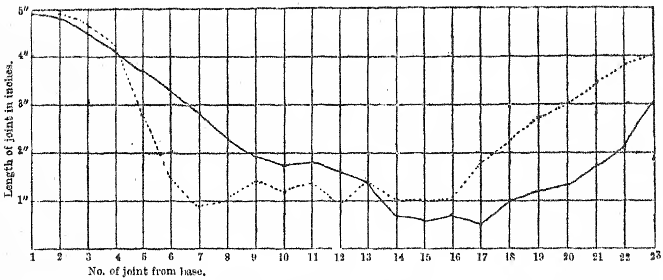
Curves were prepared of the averages of the lengths of the joints in different parts of the canes. But to prepare proper averages turned out to be a very difficult and puzzling matter. The following plan was ultimately adopted. The average number of joints was obtained and this formed the basis for each variety. Then the average lengths were taken of the joints, commencing with the lowest, and proceeding upwards until it became evident that some of the joints of the shorter canes were no longer mature. Then the reverse process was adopted and the lengths were averaged, commencing at the top joint, one-tenth of an inch long, and working downwards to the mature joints. The actual junction of these two curves in the middle was made a matter of compromise after studying the whole series, but care was taken to make the curve as uniform as possible at the point of junction. There are obvious

[1] It was not possible to commence the measurements at the very base of each shoot, but each cane was cut at ground level. There was no earthing up of the canes in the field.

objections to this method,[1] but I would refer to the two series of figures given below for *Lalri* canes (2) and (15) which had 16 and 25 joints respectively. A little study of these series will show that there are very considerable difficulties in the way of obtaining an average.

Partly owing to these difficulties, the curves were very carefully worked out in different ways, and, at the time, it occurred to me that they might be published. But the insufficient number of measurements taken at six months made this inadvisable. In, however, comparing the two series it took very little time to note that all the varieties agreed in presenting some very curious anomalies. I have chosen the *Katha* curves to illustrate these.

Length of joint in Katha.



It is seen that the six months cane starts with an average length of joint of 1", while the ten months cane starts with a 2" joint. The curve is therefore higher from the start for the ten months canes; this continues markedly for the first eight joints, when the two curves run more or less parallel; at the eleventh joint the six months curve passes upwards, crosses the other curve and continues above it until the 20th joint when, with a very

[1] Reference is invited to Table II. The plan adopted involves repeating some of the middle joints of the canes of Series (I) and omitting some of the middle joints in Series (II). This has the effect of steepening the curves of Series (II) and flattening those of Series (I), both of which results are desirable.

quick descent, it again crosses the ten months curve and finishes. The latter parts of the two curves differ in that the ten months curve descends in a much more gradual manner. Similarly related curves were obtained in all the varieties examined, except *Dhaulu*, but in this case the two sets of canes came from different plots and the results are not fairly comparable.

In comparing the curves of these two periods of growth, there are three points which require explanation. (1) The terminal joints decrease in length much more slowly in the ten months canes, (2) there are comparatively few joints added during the period between September and January, and (3) the basal joints are considerably longer in the older canes and the maximum length is much more quickly reached.

The first point is, I think, easily explained, in that the six months canes were growing rapidly, and their end joints showed this in marked differences in length. On the other hand, growth had ceased in the ten months canes and the joints formed at this period remain practically stationary. Such leaves as are formed towards this period remain small and stunted, and are frequently dried up by frost. The figures for the other varieties can be obtained from the Table of measurements preceding. In this table the numbers of joints at the ends, under two inches in length, are given for each variety at six and ten months, and exactly the same phenomenon is to be noted in each case.

The explanation of the second point is, at first sight, easy enough, on the assumption that few joints are added after September. But a study of the figures more carefully shows that many terminal joints in the older canes must be considered new, or we have the curious anomaly that the terminal joints actually decrease in length with age. A similar difficulty is experienced when trying to explain the third point, for if the curves are comparable, it is obvious that the basal joints increase in length throughout the plant's growth. Such an increase is, however, hardly possible, when one considers the mode of growth and maturing of the joints

of the cane, the hardness of the rind and the deposition of waxy and silicious incrustations.

There are thus obvious discrepancies between the two curves. Let us take the case of *Lalri*, where the following are the average lengths in inches of successive joints in the six and ten months canes :—

(*a*) six months, 1·6, 2·0, 2·5, 2·9, 3·3, 3·7, 3·7, 3·9, 3·9, 4·6, 4·2, 3·7, 3·3, 3·3, 3·2, 2·0, 0·7, 0·4, 0·1 (18·6 joints).

(*b*) ten months, 2·9, 3·7, 4·0, 4·4, 4·3, 4·5, 4·7, 4·1, 4·0, 3·9, 3·1, 2·2, 1·5, 1·0, 0·6, 0·3, 0·1 (17·2 joints).

Here, as in *Katha*, the basal joints are longer in the ten months canes, and the maximum is more quickly reached, there are five terminal joints under two inches in length in the ten months canes and only three in the six months canes, while there are even fewer joints in the older canes than in the younger. An examination of the full set of measurements at ten months brings out the fact that the canes vary a good deal among themselves as regards the length of the joints in different parts. The extremes may be exemplified by the following :—

Lalri, Cane No. 2.—4·5, 4·9, 4·9, 5·0, 4·3, 5·1, 4·8, 3·4, 2·9, 2·4, 1·2, 1·1, 0·9, 0·6, 0·2, 0·1 (16 joints).

Lalri, Cane No. 15.—0·9, 1·0, 1·0, 0·9, 1·0, 1·5, 1·7, 2·1, 2·7, 3·2, 3·4, 3·7, 4·3, 4·0, 4·6, 4·5, 3·2, 3·7, 3·3, 2·4, 1·6, 1·2, 0·7, 0·5, 0·1 (25 joints).

And a further study of the whole series shows that the canes measured can be divided into two, practically equal sets, one set with canes more or less similar to Cane No. 2 and the other approximating to Cane No. 15. I have chosen *Kahu* for the full demonstration of this peculiarity, and reproduce the full set of measurements of the lengths of the joints at ten months (Table II). The 20 canes have, however, been separated into two series, the first commencing with long joints and quickly attaining the maximum, usually also with fewer joints as in Cane No. 2 of *Lalri*, and the second commencing with short joints and slowly attaining the

maximum and usually with many joints as in Cane No. 15 of *Lalri*. One of the *Kahu* canes, No. 6, is abnormal in that it combines, so to speak superposed, the characters of the two series, and accordingly has two maxima. Because of the longer basal joints, I have included it in Series I, although its proper place should undoubtedly have been between the two series.

These two series exhibit in an exaggerated form the differences, noted above, between the earlier joints of the six months and ten months canes (shown in the *Katha* curves). Now a study of the measurements of the whole of the six months canes shows that they usually belong to the second series, the lower joints being moderately short and gradually increasing in length up the stem. The canes of the first series are practically absent in the six months crop and the suggestion is natural that the canes of this series are unrepresented there or very slightly so, are, in fact, new formations, late-formed canes which had not reached sufficient size to be measured as mature canes in September.

TABLE II.—LENGTHS OF JOINTS (IN INCHES) OF 20 KAHU CANES, 10 MONTHS OLD.

SERIES I.—*Canes with few joints long at base.*

1	4·4	4·7	4·8	4·5	4·9	4·8	4·4	3·8	3·8	3·6	..	..	..	..	..	..	..	..	..	..	..	..	..	3·2	2·4	1·9	1·8	1·0	0·7	0·3	0·1
2	3·8	4·5	4·7	4·7	4·9	4·2	3·4	3·8	3·6	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3·2	2·5	2·1	1·7	1·0	0·5	0·3	0·1
3	3·8	4·0	4·3	4·1	4·4	4·2	4·0	3·3	3·1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2·7	2·6	1·8	1·4	0·8	0·5	0·2	0·1
4	3·7	3·9	4·9	5·1	5·3	5·0	4·6	3·5	3·1	3·0	2·4	..	..	..	..	..	..	..	..	..	..	..	..	1·8	1·9	1·5	1·1	0·9	0·5	0·2	0·1
5	3·5	4·4	4·5	4·3	4·6	5·1	4·4	3·5	3·1	3·0	2·6	2·0	..	..	..	..	..	..	..	..	..	..	..	2·1	1·4	0·8	0·5	0·6	0·4	0·2	0·1
*6	3·2	4·0	3·9	4·4	3·9	3·6	2·9	2·6	2·3	2·7	3·2	3·2	3·2	4·0	3·5	3·4	..	..	..	..	..	..	..	3·4	2·6	1·5	1·4	0·8	0·8	0·3	0·1
7	3·1	4·3	4·8	6·0	5·6	5·3	5·1	4·5	3·6	3·9	3·4	..	..	..	..	..	..	..	..	..	..	..	..	2·9	2·2	1·7	1·1	1·1	0·4	0·2	0·1
8	3·1	4·1	4·4	4·4	4·5	4·3	4·1	3·5	3·4	3·9	2·8	..	..	..	..	..	..	..	..	..	..	..	..	2·8	2·5	2·0	2·8	0·9	0·5	0·2	0·1
9	2·8	4·0	4·5	4·8	4·8	4·7	4·6	4·8	4·5	4·2	3·0	2·1	..	..	..	..	..	..	..	..	..	..	..	2·4	2·2	1·4	1·4	0·9	0·5	0·2	0·1
10	2·7	4·0	4·2	4·5	4·6	4·6	4·7	4·5	4·2	4·0	3·4	3·1	..	..	..	..	..	..	..	..	..	..	..	2·5	2·1	1·6	1·1	1·1	0·7	0·3	0·1
Av.	3·4	4·2	4·5	4·6	4·7	4·6	4·2	3·8	3·5	3·4	2·9	..	..	..	..	..	..	..	..	..	..	..	..	2·7	2·2	1·6	1·5	0·9	0·5	0·2	0·1

SERIES II.—*Canes with many joints short at base.*

11	2·7	3·2	3·4	3·6	3·8	3·5	3·5	3·7	3·5	3·5	3·2	3·4	3·3	3·0	2·0	..	..	..	..	..	..	..	..	2·0	1·9	1·3	1·1	0·9	0·6	0·2	0·1
12	2·5	3·1	4·0	3·8	3·7	3·5	4·0	4·2	3·6	3·3	3·2	3·1	2·5	..	..	..	..	..	..	..	..	..	..	2·5	2·1	1·7	1·2	0·9	0·6	0·4	0·1
13	2·5	3·2	4·0	4·4	4·5	4·7	4·5	4·3	5·4	5·5	4·3	3·7	3·5	2·7	2·5	..	..	..	..	..	..	..	..	2·4	2·0	1·5	1·2	0·8	0·5	0·3	0·1
14	2·0	3·1	3·9	3·9	4·3	4·2	4·3	4·5	4·2	3·8	3·1	3·9	..	..	..	..	..	..	..	..	..	..	..	2·5	1·8	1·7	1·1	0·7	0·4	0·2	0·1
15	2·0	2·2	3·1	4·0	4·5	4·6	5·1	4·8	4·1	3·5	3·9	3·5	3·3	2·8	..	..	..	..	..	..	..	..	..	2·6	2·6	2·0	1·5	1·0	0·7	0·3	0·1
16	1·9	3·4	4·3	4·3	4·5	4·6	4·7	4·8	4·3	3·8	3·3	3·3	..	..	..	..	..	..	..	..	..	..	..	2·9	2·1	1·8	1·3	0·8	0·5	0·2	0·1
17	1·9	2·1	2·8	3·4	3·7	3·6	3·5	3·4	3·8	4·0	4·4	4·0	3·7	3·0	2·5	..	..	..	..	..	..	..	..	2·4	2·1	1·4	1·1	0·8	0·6	0·3	0·1
18	1·6	2·1	3·2	3·3	3·6	3·7	3·5	3·5	3·4	3·7	4·6	4·1	3·5	3·3	2·9	2·5	2·4	..	..	..	..	..	..	2·3	1·8	1·6	1·2	0·8	0·6	0·4	0·1
19	1·2	1·1	1·5	1·6	1·7	1·6	1·9	2·2	2·7	3·1	3·0	3·1	3·1	3·3	3·5	3·8	3·5	3·2	2·9	2·6	2·7	2·4	2·4	1·4	1·8	1·1	0·8	0·7	0·5	0·2	0·1
20	1·0	1·1	1·5	1·9	2·3	2·3	3·0	3·1	3·3	3·5	3·8	3·7	3·3	3·3	3·4	3·1	3·0	2·3	2·0	..	..	..	..	1·7	1·5	1·0	0·7	0·6	0·4	0·2	0·1
Av.	1·9	2·7	3·2	3·4	3·7	3·6	3·8	3·9	3·8	3·8	3·7	3·6	3·2	2·8	2·5	..	..	..	..	..	..	..	..	2·3	2·0	1·5	1·1	0·8	0·5	0·3	0·1

* Abnormal cane, with two maxima, whose correct place would be between the two series.

If this interpretation is correct the discrepancies in the six and ten months curves disappear. The longer basal joints in the ten months curve are due to the inclusion of a large number of late-formed shoots with this character, and the comparatively small increase in the number of joints in the ten months canes is due to these late-formed canes having comparatively few joints. It has been noted in the field that the canes in September are nearly, if not quite, as high, on the average, as in January, and this can also be explained by the inclusion in January of a large number of late-formed canes which are shorter than the others. There are, on the other hand, probably a considerably larger number of mature canes in each clump, and therefore a heavier crop.

It is quite possible that the relative proportion of these late-formed canes will be found to differ in the various kinds of cane grown. In fact, there are some indications that this is the case. From an examination of the individual measurements taken at ten months we find that *Lalri*, *Kansar*, and *Kahu*, the three thickest canes, have, each of them, ten few-jointed canes with long basal joints out of the twenty. *Dhaulu of Gurdaspur* has six (?), *Katha* seven and *Kanara* four. This seems to indicate a different mode of growth in the three first varieties, apparently in the direction of a less rapid early development, which may turn out to be of diagnostic as well as of agricultural value. No data are available as to the chemical properties of the two series of canes, but it would be worth while to make some observations on the point. With regard to their other characteristics, *Lalri* and *Kahu* have been selected and the results of an analysis are shown in the table appended.

TABLE III.

Summary of characters of the two kinds of canes in Kahu and Lalri ten months crops.

	Number of joints in the cane.	Total length of cane.	Av. length of mature joint.	Av. length of shortest (basal) joint.	Av. length of longest joint.	Number of top joints under 2″ long.	Thickness of mature joint in decimals of an inch (lateral+medial). Base.	Middle.	Top.	Length of cane divided by thickness at middle.
Kahu.										
Whole 20 canes	21·5	57·3″	3·4″	2·7″	4·7″	6	75+76	75+78	72+76	74
Series (I) 10 canes ..	19·0	54·7″	3·8″	3·4″	4·9″	6	72+73	71+74	67+71	72
Series (II) 10 canes ..	23·0	59·7″	3·2″	1·9″	4·4″	6	77+78	80+83	76+89	76
Lalri.										
Whole 20 canes	17·2	50·0″	3·9″	2·9″	5·2″	5	51+54	54+56	54+56	91
Series (I) 10 canes ..	15·1	46·4″	4·3″	3·7″	5·6″	5	50+52	52+55	52+56	87
Series (II) 10 canes ..	19·5	53·7″	2·7″	2·3″	4·7″	5	53+56	55+58	55+56	95

These figures are very remarkable in their uniformity, those for the whole series of 20 being in every case the mean between those of Series (I) and Series (II). From a careful study of the table it appears that the canes of Series (I) have fewer joints, but longer ones, especially at the base, and are thinner and shorter canes. They have thus considerably less cubical content, and the variety with a larger proportion of them will presumably produce a smaller crop, other things being equal. We have seen reason for assuming that they are late-formed shoots. But it is seen that they are thin and therefore have nothing to do with "water-shoots" or "gourmandisers"—those thick, long-jointed late-formed shoots, so typical of certain varieties and conditions. These water-shoots are characterised by enormous thickness, extremely rapid growth, much water and little or no sugar content, so that they are valueless from the crop point of view.

Botanically, the peculiar mode of growth of the late-formed shoots is not difficult to understand. The shoots first formed in the cane appear at a time when the plant is small, with limited foliage and root mass. Their joints are, naturally, short at first and only gradually increase in length up the stem, for the growing power is limited. A greater production of leaves and roots is desirable and these can only arise at the nodes and, the shorter the joints, the more nodes are available. Later on, when there is full vigour of growth, with a dense mass of leaves and a great root system, the new shoots will grow more rapidly, fewer leaves and roots are needed and the joints will consequently be longer. From another point of view, the *thinness* of these late-formed canes is of interest, for thinness combined with elongation of joints is a character usually exhibited by shoots or plants growing in the shade. The late-formed shoots, heavily overshadowed by the mass of cane leaves above them, will naturally strive upwards after the light. In all probability, these two factors, of more powerful growth and striving after light, both have their influence in determining the mode of growth of the later formed cane shoots.

KATHA.

1. General remarks as to distribution and agricultural and chemical characters.

A. The most universally grown of any variety in the Province. It is found (1) extensively grown under *barani* (rainfed) conditions in submontane tracts, where the rainfall, although moderate, is insufficient for other kinds,

(2) under well and canal irrigation in submontane tracts slightly further removed from the hills,

(3) in low lands along river and canal banks and on the borders of swamps, where the absence of drainage prevents other varieties from growing. In these localities *rab* is generally made, as the crop never properly ripens,

(4) in the Canal Colonies in the southern districts of the Province, as it withstands the hot, dry climate better, than the other varieties.

A thin, reddish cane, very hardy and with great tillering powers, capable of withstanding considerable drought, flooding and, to a less extent, frost. *Katha*, sometimes called *Chan*, ripens earlier than any other variety. The leaves are very persistent and it is consequently a difficult cane to strip. The rind is hard and the cane is therefore not used for chewing. The juice is not of a good colour but is much liked for drinking. It is said to be more wholesome than that of *Dhaulu* as the latter, although of a nice, white colour, produces an excess of saliva after drinking. The juice is small in quantity compared with the other varieties but contains a good percentage of sugar. The *gur* is said to keep better than that of the other local canes. It is said to have arisen from the wild *Kahi* grass which grows in swampy lands of the submontane

tracts. A good crop yields 30 maunds of gur per acre. (The rind of this variety is much valued for its strength and, when crushed in the wooden *belna* mill, is used extensively for mats, cordage for mhotes, etc., especially around Jullunder. The word *Katha* means red. Height at 6 months 7-8 feet; at 10 months 8-9 feet at the Gurdaspur Farm. Erect, in bunches, often falling where irrigated. Sometimes tied in cocks or otherwise supported. The older leaves stand out rather markedly from the stem and are widely separated. The variety is a good deal attacked by smut and an agaric (*Fomes lucidus* according to Dr. Butler) was found growing rather profusely in some parts of the field at harvest. Rooting was seen on the lowest four joints and shooting was not a marked character in the field. C. A. B.).

B. A hardy cane yielding *shakkar* on good soil. The variety is classified as frost-resistant on the results of the last three years experiments. The average composition of the juice (average of the last three years) is :—

Month.	Sucrose %	Invert sugar %
November	12·75	2·80
December	15·39	1·23
January	15·46	1·51
February	16·48	0·80

It is fully ripe about the beginning of February. The *gur* or *shakkar* made from various specimens of the variety yielded a sucrose content from 56·72 to 73·64 per cent.

(The details of sections A and B have been kindly provided by Messrs. Southern and Barnes respectively).

2. List of specimens examined.

Young canes, 6 months old.

(*a*) Gurdaspur, September 1913. Irrigated, on the farm lands; 18 canes examined, the foliage measured and drawn, and the crop photographed.

(*c*) Lyallpur, September 1913. Irrigated farm crop. The field photographed for habit. It is to be noted that the leaves were remarkably narrow.

Mature canes, 10 months old and ready for reaping.

(*b*) Gurdaspur, January 1914. The same irrigated farm plot ; 25 canes examined of which 20 were measured. Canes drawn, painted and photographed to scale ; field photographed.

Canes about 12 months old.

(*d*) Jullunder, 10th March 1913. Irrigated ryot's field, being milled in the "Belna" ; 6 canes examined, drawn and photographed to scale.

(*e*) Gurdaspur, 13th March 1913. Rainfed canes from neighbouring villages ; 6 canes examined, photographed to scale.

(*f*) Harchowal, 15th March 1913. Ryot's field ; 6 canes examined and photographed to scale.

3. General characters of the variety.

The *Katha* cane is thin, straight-sided and without prominent nodes. It is glaucous green to brown yellow at six months but turns brown or vinous towards crop time. There are characteristic red brown marks in the groove and it is affected by smut. Ivory markings are present but not abundant, usually in the upper part of the joint and often passing through the bloom band. The growth ring is distinct, becoming dark brown in old joints. The circlet of hairs is more or less persistent all the way up and there is usually a distinct scar band. The buds are moderately small, rounded and bursting more or less dorsally. They reach the growth ring and are not very well provided with hairs ; minute black hairs are not usual on them. The leaves stand out well from the stem and are narrow and grass-like ; the young leaves are sharply bent at the tips, but soon become broadly curved. The lamina is distinctly channelled at the base and the midrib comparatively wide there.

The leaf-sheath is glabrous, embraces the shoot broadly and has light coloured edges. Ligular processes are well developed, although they may be very long or almost absent in leaves of the same shoot.

4. Cane measurements.

Dead leaves at six months old.—The six months old canes had on an average 13-14 dead leaves, none of which had fallen from the stem. These canes were in full vigour, with good leafy shoots. It was found that the canes at crop time did not offer any chance of examining the foliage characters, and this was the reason for the special study of the six months canes. The leaves of the older canes were mostly dead, although still clinging to the stem and a small tuft of yellowish or brown leaves was left at the top, quite unfit for general study. This applies to all the varieties.

Length of six months canes after stripping dead leaves.—The canes averaged 4′ 1″ and the shoots 5′ 5″ long.

Total length of cane and number of joints at six and ten months.

(*a*) 6 months old canes 57·2″, including 21·6 joints.

(*b*) 10 months old canes 62·4″, with 22·6 joints.

Total length of stripped cane divided by average thickness at the middle, $l \div t$.

(*a*) 129, (*b*) 156.

From these figures it will be seen that the growth of the cane after the end of September is not very great.

Length of joints in different parts of the cane in inches.

(*a*) average of 6 canes: 1·0, 1·2, 1·6, 2·0, 2·3, 2·8, 3·2, 4·0, 4·0, 4·0, 3·6, 4·1, 3·6, 3·8, 3·6, 4·0, 4·1, 3·5, 2·2, 0·8 0·3, 0·1.

(*b*) average of 20 canes: 2·0, 2·9, 3·3, 3·7, 3·8, 4·0, 4·5, 4·3, 4·4, 4·3, 3·6, 3·4, 3·2, 3·3, 3·1, 2·7, 2·2, 1·7, 1·3, 0·9, 0·5, 0·2, 0·1.

An examination of these figures shows that the lower joints of the older canes are generally longer than those of the

younger canes, suggesting that growth in length takes place at the base of the cane. There is, however, another explanation which has already been given in a special note. It is also evident that the terminal joints of the younger canes decrease much more quickly in length than in the older; this is taken as showing that growth has largely ceased at this part of the cane.

Thickness of the cane at various points.—One of the characters of *Katha* is that the joints are of fairly uniform thickness all the way up. Measurements were taken in the 10 months old canes at the base, in the middle and at the uppermost mature joint, as follows :—Base 0·40″, middle 0·39″, top 0·41″, differences quite within the range of personal error.

5. Colour of cane.

As already mentioned, the six months old canes of *Katha* are glaucous green to brown yellow. There is hardly a trace of the rich brown colouring which later forms so marked a character of the cane. The ten months canes are apple green in the young, covered joints of the shoot, becoming glaucous green or yellow with pinkish dots and patches lower down. But when fully formed, besides greens and yellows, the joints show a prevailing violet or vinous brown which is very striking. This colour is caused by a rich brown skin under the bloom and, where the bloom is rubbed off, the cane often shows a fine brown colour.

The Bloom band is distinct at the top of the cane but becomes dulled lower down. Bloom descends over the joint, changing the green colour of young joints to glaucous green and the dark brown skin of older parts to pinkish brown or violet.

The root zone in the young canes is covered with bloom and cream coloured in the younger joints, becoming bone yellow.

The growth ring is green in the younger joints but soon becomes brownish. Later on the brown deepens, often first at the upper and lower edges of the ring, until it is a rich dark brown. The growth ring has no bloom, and its colour in old joints is similar to that of the skin beneath the bloom layer.

Blushing of the stem on exposure does not appear to be common in *Katha*, but young canes take on a faint pink colour when cut, and older ones become more or less red in time.

Blackening is not marked but is occasionally seen in old canes.

The Groove has black incrustations of small rounded bodies and red brown marks made up of fine, parallel lines.

Ivory markings are usually present but not in great quantity, being chiefly confined to the upper parts of joints and sometimes passing through the bloom band. They are seen not infrequently to change to splits and are present in the older root zones. In the young, upper parts of mature canes, the markings become more abundant and here take on the character of those in *Dhaulu*, long close parallel lines in the middle or upper third of the joint. Most canes seem to have one young joint marked in this curious way.

Splitting is not infrequently met with and these splits obviously arise from the ivory markings in most cases. There is a *scar band* rather than a *scar line* in *Katha*.

6. Character of the joint.

Thickness, ovalness in section.—*Katha* is the thinnest cane in the Punjab and perhaps in India. Quite a number of specimens of *Saccharum spontaneum* have been met with which were thicker. But it is to be noted that the canes at Gurdaspur appear to be rather thinner than usual, and I am told that *Katha* becomes much thicker eastward around Jullunder and Ludhiana. The following measurements were taken in the middle of the canes examined :—

(*a*) of 18 canes six months old, average 0·48″.
(*b*) of 20 canes ten months old, average 0·40″ (0·35″ + 0·47″).
(*d*) of 6 canes, thickest 0·51″, thinnest 0·42″.
(*e*) of 6 canes, thickest 0·44″, thinnest 0·34″.
(*f*) of 6 canes, thickest 0·45″, thinnest 0·35″.

The canes in *Katha* are seen to be well under half an inch in diameter.

As regards *ovalness*, they are remarkably cylindrical, the ovalness found in all canes being very slightly developed as is seen below, lateral + medial :—

(*b*) Bottom of cane 0·40″ + 0·42″.
  Middle of cane 0·40″ + 0·41″.
  Top mature joint 0·41″ + 0·42″.

(*d*) Thickest cane 0·51″ + 0·54″, thinnest cane 0·42″ + 0·43″.

(*e*) Thickest „ 0·44″ + 0·50″, thinnest „ 0·34″ + 0·35″.

(*f*) Thickest „ 0·45″ + 0·47″, thinnest „ 0·35″ + 0·37″.

Length of mature joints (*deducting top joints under* 2 *inches long*)

(*a*) of 6 canes the average mature joint was 3·1″, average longest 4·5″, average basal 1·0″.

(*b*) of 20 canes the average mature joint was 3·7″, average longest 5·3″, average basal 1·0″.

(*d*) The joints of 6 canes were judged to be from 3″ to 6″ long.

(*e*) Do. do. 4″ to 7″ long.

(*f*) Do. do. 4″ to 7″ long.

Shape viewed medially.—The joints are usually thickest at the leaf-scar, then at the junction of the root zone and growth ring or at the bloom band. The middle of the joint is slightly thinner, and the general shape is therefore biconcave. But the differences are so small that the joints may be described as practically straight-sided.

Shape viewed laterally.—The relative thicknesses of the different parts of the joint are as in the median view. But there is sometimes a slight tendency towards a bulge below behind, so commonly met with in other canes, and this gives a slight appearance of concavo-convexity.

The leaf-scar is practically horizontal and there is not usually a well marked lip under the bud. Sometimes however a distinct short lip has been noted. The end of the leaf-scar is not markedly decurrent.

The circlet of hairs is usually persistent right up the stem and is composed of short parallel hairs.

The groove varies a good deal, being present, indicated or entirely absent. When seen it is not usually deep, but rather a flattened region. The black incrustations and red brown marks have been referred to already.

The root zone is moderately narrow, not protruding, except sometimes in the lower, older joints. It has a distinct tendency to narrow downwards, making the growth ring look thicker than it really is. There are two or three rows of indistinct eyes, often tubercled when old, occasionally ivory markings cross the eyes in the older joints.

The growth ring is moderately broad and clearly marked with definite upper and lower boundaries. This ring is one of the most striking characters of the cane, and has been already described, as regards its colour.

7. Bud.

Shooting is not well developed in *Katha.*

Bursting is usually more or less dorsal, the apex of the bud being either in the middle or between the middle and the top.

The buds are small and flat, generally reaching the growth ring; rounded, almost circular, sometimes emarginate at the top because of the flanges.

They arise at the leaf-scar and there is no *cushion.*

The *flanges* arise about the middle and extend broadly round the apex. They are sometimes emarginate or truncated above and of a dark brown colour.

Bristles are usually sparse, but present round the upper margin; *basal patches* are better developed, sometimes of white parallel hairs and sometimes felt-like.

Minute black hairs are not characteristic and are often absent.

8. Leafy shoot.

Colour, dark, slightly bluish green.

There are 5-6 leaves in the *terminal tuft* (borne on the top 2″ of the visible shoot).

The *leaf ends* are erect at first, but soon become bent at a sharp angle. Later on they are broadly curved.

The *number of terminal joints under* 2″ is three in the six months canes, and six in the ten months.

(*a*) 2·2″, 0·8″, 0·3″, 0·1″.
(*b*) 2·2″, 1·7″, 1·3″, 0·9″, 0·5″, 0·2″, 0·1″.

9. Leaf sheath.

Length ; average longest.—Average of the six canes in inches :— 5·7, 7·3, 7·5, 7·7, 8·0, 8·2, 8·8, 9·2, 9·7, 10·3, 10·7, 11·2, 11·0, 10·8, 10·5, 10·2, 9·8, 10·0, 9·8, 9·9 (8·9, 5·9, 1·1, 0·2).

The longest sheaths were 10·7, 12, 12, 12, 10, 11·2, averaging 11·3.

Very slightly *bloomed.* Turning light clear brown when just dead in the six months canes, thus differing markedly from *Dhaulu* (q. v.). Not blushing red on exposure in the ten months canes, and here also differing from *Dhaulu.* The *scarious border* of the leaf-sheaths does not appear early, and the *edges* of the young sheaths are light coloured, and not red brown as in *Dhaulu.*

Glabrous, without spines ; *hairs* between the veins behind minute, puberulous, hardly distinct under the lens.

Base of leaf-sheath *clasping* the stem rather widely, and passing one and a half times round the circumference.

Proportion of base of lamina to top of sheath 0·55 : 0·76.—In three other cases the proportions were 8 : 12, 8 : 12, and 7·5 : 11, thus leaving room for ligular processes.

Ligular processes short, tooth-like, or long and narrow, usually on one side only.

Ligule rather narrow, widening in the middle and with minute hairs on the edge.

10. Lamina.

Width.—Very narrow, usually about 0·6″, but occasionally reaching 0·8″.

Length, average of 6 six months canes ;—2′0″, 2′1″, 2′2″, 2′4″, 2′5″, 2′8″, 2′10″, 2′11″, 3′2″, 3′2″, 3′6″, 3′7″, 3′9″, 3′9″, 3′9″, 3′8″, 3′8″, 3′5″, 3′6″, 3′8″, 3′9″, 3′5″, 2′11″.

The longest laminas in the six canes were 3′9″, 4′1″, 4′1″, 4′2″, 3′6″, 3′11″, averaging 3′11″.

Proportion of length to width 58·8 to 1.

Markedly *channelled* at the base.

Transverse marks yellowish green, becoming darker below; very slightly bloomed. *Serrature* strong, persistent.

Proportion of midrib to lamina at 1″, 33 : 100, at 6″, 27 : 100, at 12″, 16 : 100.

DESCRIPTION OF PLATE.

KATHA.

1, Middle and 2, top of a ten months cane. The growth rings become darker brown as the joints mature; the circlets of hairs are distinct and persistent; in the middle of 2 there is one young joint with many ivory markings.

3. The upper part of a six months cane, showing the base of the sheath clasping the stem widely, and well marked ligular process.

4. Lamina and sheath at the point of junction; the lamina is sharply infolded and there is a well marked ligular process on one side. The ligule is seen at the point of junction.

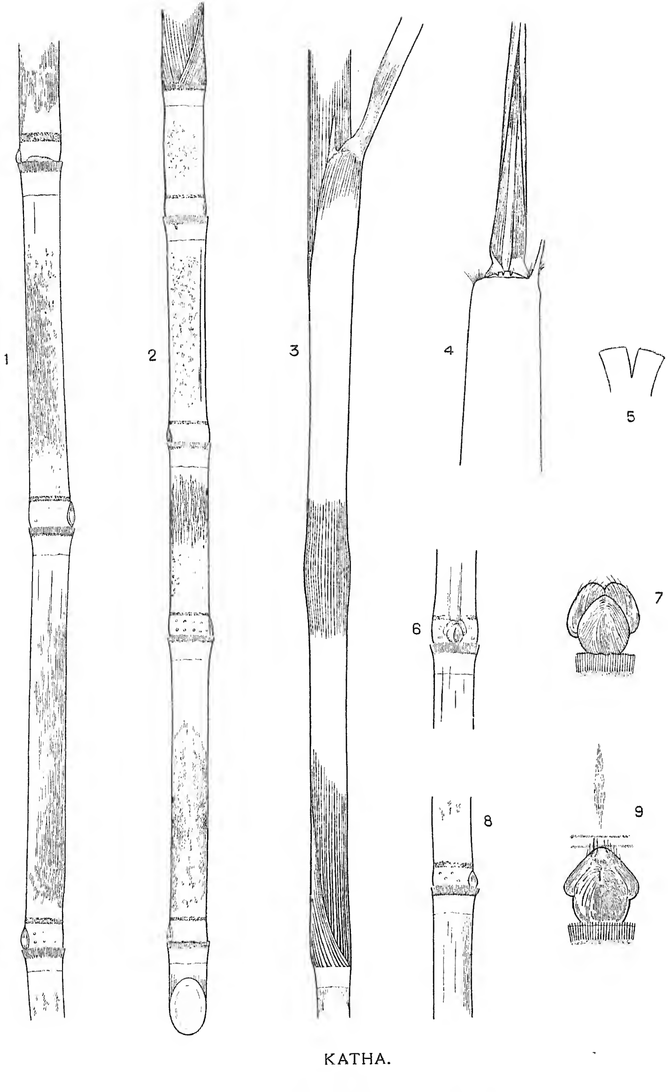
5. Part of the ligule with a fringe of minute hairs on its edge.

6. Node of a six months cane with circlet of hairs and small bud reaching the well marked growth ring. There is a distinct groove. The ivory markings cross the bloom band.

7. The bud of 6 enlarged, with few bristles and moderately distinct basal patches. The flanges are emarginate.

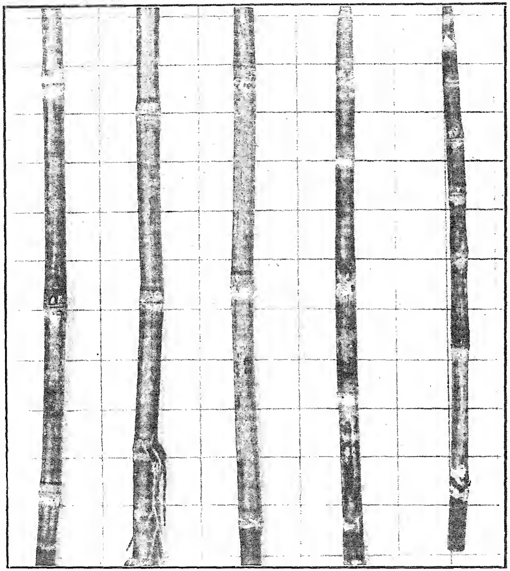
8, 9. Node of a ten months cane with its bud. The bud will burst dorsally and there is a distinct red brown mark in the groove made up of fine parallel lines.

PLATE I.

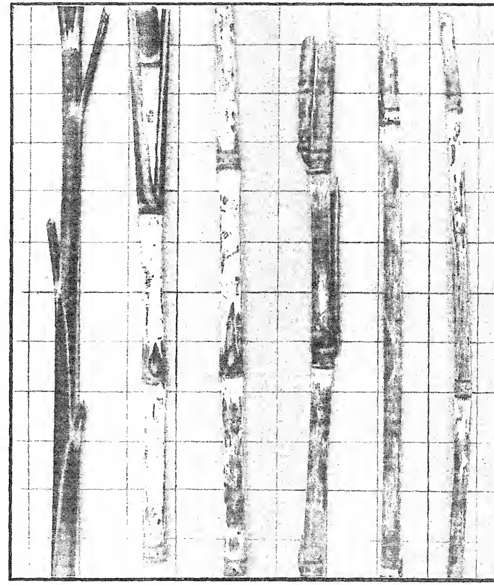


KATHA.

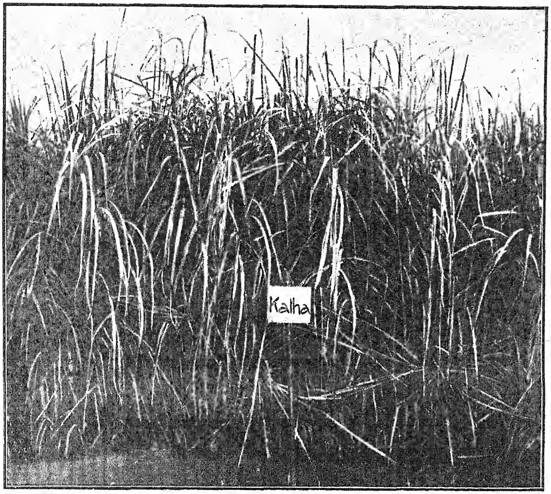
PLATE II.



KATHA.



SACCHARUM SPONTANEUM.



KATHA, 6 months old, Gurdaspur.

KATHA, 6 months old, Lyallpur.

LALRI.

1. General remarks as to distribution and agricultural and chemical characters.

A. Extensively grown on well and canal irrigated land in the Karnal, Rohtak, and Delhi districts. The soil and climate of this tract are well suited to sugarcane cultivation and the yields are higher here than in any other part of the Province. *Lalri* is a cane of the *Katha* type, not unlike the *Chan* of Ambala but slightly thicker. It is said locally to be a degeneration from *Saretha*, but this is very doubtful. It is thinner than *Kansar*, matures later than *Katha*, but slightly earlier than *Dhaulu of Phillaur*. The latter cane and *Lalri* are extensively grown in the north of Karnal but here the *Dhaulu* ceases and *Lalri* takes its place further south. The yields of *Lalri* are very heavy, 50 maunds of *gur* being obtained from a good crop. (Height of the canes at Gurdaspur 8-9 feet at six months. Like *Katha* but taller and thicker and with broader leaves; smaller and shorter than *Kansar* and the leaves spreading rather less; some of the leaf tips soon broadly angled as in *Katha*. Tillering good, but the canes lodging with irrigation and with heavy crops. Suffering from smut. The six months canes were rooting for the first four joints and had about three shot buds each.—C. A. B.)

B. A hardy cane, yielding *gur* on good soils. The variety is classified as frost resistant on the results of the last two years' experiments. The average composition of the juice (average of the last two years) is :—

Month.	Sucrose %	Invert sugar %
November	11·56	2·34
December	12·56	0·84
January	14·31	0·70
February	16·21	0·45

It is fully ripe about the middle of February.

(For the details in these sections I am indebted to Messrs. Southern and Barnes.)

2. List of specimens examined.

The canes of this variety were all from Gurdaspur Farm and include six months and ten months canes from the same plot. The former were, as usual, relied on for foliage characters, as these cannot be studied in ripe canes in the north.

Young Canes, six months old.

(*a*) Gurdaspur, September 1913. Irrigated farm plot ; 12 canes examined of which six were measured as to foliage and joints ; canes drawn and field photographed.

Mature Canes, ten months old.

(*b*) Gurdaspur, January 1914. Irrigated farm plot ; 25 canes examined of which 20 were measured as to length and thickness of joints. Canes drawn and painted and photographed to scale and field photographed.

3. General characters of the variety.

The *Lalri* canes examined were moderately thin, hard, straight-sided and without prominent nodes. They were evidently a *Katha* cane but thicker and shorter. The young canes were glaucous grey or white from excess of bloom ; later on the skin became brown under this bloom, and the cane vinous, the brown showing where the bloom was scraped off. The general colouring of *Lalri* was more vivid than in *Katha* or *Kansar*. The groove had occasional red brown marks as in *Katha*. Ivory markings short and few, usually in upper parts of the joints and occasionally passing through the bloom band. Growth ring very dark brown in lower joints of mature canes. Circlet of hairs persistent, strong, often brownish below, and sometimes changing to a felt or even disappearing higher up the stem. Scar band present. Buds small, rounded or pointed, usually bursting rather apically, but sometimes dorsally below ; usually reaching the growth ring except in some lower joints ; hairs not well developed, but minute black hairs present. Leaves as in *Katha* but broader, including the sharply bent tip in young leaves,

less channelled at the base and with proportionately narrow midrib. Leaf-sheath as in *Katha;* ligules distinct, tooth-like or long.

4. CANE MEASUREMENTS.

Dead leaves at six months old.

The average number of dead leaves in the six canes was 12.

Length of cane and of shoot after stripping these.

Average length of cane exposed 3′ 3″, of shoot 4′1″.

Total length of cane and number of joints at six and ten months.

(*a*) Total length 51·8″, number of joints 18·6.
(*b*) Do. 50·0″, do. 17·2.

Total length divided by average thickness at the middle, $l \div t$.

(*a*) 92, (*b*) 91.

Length of joints in different parts of the cane, in inches :—

(*a*) 1·6, 2·0, 2·5, 2·9, 3·3, 3·7, 3·7, 3·9, 3·9, 4·0, 4·2, 3·7, 3·3, 3·3, 3·2, 2·0, 0·7, 0·4, 0·1 ; 18·6 joints.

(*b*) 2·9, 3·7, 4·0, 4·4, 4·3, 4·5, 4·7, 4·1, 4·0, 3·9, 3·1, 2·2, 1·5, 1·0, 0·6, 0·3, 0·1 ; 17·2 joints.

These figures are rather puzzling. In the first place there is something wrong in that there are more joints in the younger canes than in the older, although the material was drawn from the same plot. Secondly, the older canes apparently have longer joints at the base, suggesting a prolonged growth in this part of the plant such as is not justified by one's knowledge of anatomy. These facts have led to a more careful study of the columns of measurements, with the result that it has been demonstrated that there are two kinds of canes in the clump, longer, older, with shorter joints (especially at the base), and shorter, younger, with longer joints (especially at the base). And it has furthermore been shown that there are more of these younger canes in the older clumps. This subject has been fully dealt with in a separate note.

Thickness of the cane at various points.—This undergoes little change as we pass up the cane, *Lalri* being remarkably uniform in this respect.

(*a*) Occasionally narrower at the base, but soon uniform upwards.

(*b*) Average of 20 canes, base 0·51″; middle 0·54″; top 0·54″.

5. Colour of cane.

The young canes are glaucous grey or white, green where the bloom is rubbed off, to yellow in the lower parts of the joints. In older canes the colour is, as in *Katha* and in *Kansar*, rather difficult to describe, but there is plenty of vinous colouring. On the whole, the red brown skin of *Lalri* is of a more vivid character than in the two allied forms, and is well seen where the bloom has been accidentally rubbed off, as well as in the blotches in the green, upper, younger parts of the cane. *Blackening* occurs here and there and is usually confined to the upper part of the joint. The *bloom*, as has been indicated above, is remarkably heavy, descending over the joint as a white layer, lightly over the root zone, but only dulling the growth ring. The *growth ring* is light brown in young canes, in older ones green in its upper joints and very dark brown in the lower ones. *Blushing* is not apparent in exposed parts. There is a well marked blackish grey *scar band*, between the bloom layer and the leaf scar. The ivory markings are few and short, usually confined to the upper part of the joint, occasionally passing through the bloom band. Here and there upper joints have massed markings as in *Dhaulu* and *Katha*. The *root zone* is sometimes marked by small brown slits. *Splits* are practically absent but sometimes arise from ivory markings. The *groove* has sometimes the red brown marks composed of fine parallel lines so characteristic of *Katha*.

6. Character of the joint.

Thickness, ovalness. *Lalri* is not such a thick cane as *Kansar*. The cane is remarkably cylindrical and ovalness is hardly perceptible as is seen from the following measurements, lateral + medial: —

(*b*) Base 0·51″ + 0·54″; middle 0·54″ + 0·56″; top mature 0·54″ + 0·56″.

Length of mature joints.

(*a*) average 3·3″, average longest 4·6″, average basal 1·6″.

(*b*) average 3·9″, average longest 5·2″, average basal 2·9″.

Shape viewed medially.—Thickest at leaf-scar and root zone then at growth ring; hence, slightly biconvex; but practically straight-sided.

Shape viewed laterally.—Very slightly zig-zag; traces of swelling below behind, giving the joints occasionally a slight concavo-convexity.

Leaf scar practically horizontal, very occasionally slightly descending, and with a very short *lip*.

Circlet of hairs persistent, strong, brownish below. Occasionally present all the way up, but more often becoming a felt in the upper parts or even disappearing there.

Groove present, shallow, or absent; where present, seen all the way up the joint; occasionally showing the characteristic brown red marks of the *Katha* group.

Root zone usually slightly swollen or barrelled, especially in the lower joints; slightly bloomed; with moderately distinct eyes in two to three rows; sometimes with ivory markings, especially in the lower joints.

Growth ring distinct and not very broad in the specimens examined; its colour referred to above.

7. Bud.

Shooting noted on the average in the three lowest joints in the young canes. *Bursting* usually rather apical, but dorsal in some of the lower joints.

The buds small, rounded, or pointed, usually reaching the growth ring except in a fewer lower joints; if exceeding the growth ring, ovate triangular. Arising at the leaf-scar and without any trace of *cushion*.

Flanges not apparently well developed; *basal patches* present and sometimes regularly formed, white and glistening; *minute black hairs* present, especially below.

(*a*) Occasionally narrower at the base, but soon uniform upwards.

(*b*) Average of 20 canes, base 0·51″; middle 0·54″; top 0·54″.

5. COLOUR OF CANE.

The young canes are glaucous grey or white, green where the bloom is rubbed off, to yellow in the lower parts of the joints. In older canes the colour is, as in *Katha* and in *Kansar*, rather difficult to describe, but there is plenty of vinous colouring. On the whole, the red brown skin of *Lalri* is of a more vivid character than in the two allied forms, and is well seen where the bloom has been accidentally rubbed off, as well as in the blotches in the green, upper, younger parts of the cane. *Blackening* occurs here and there and is usually confined to the upper part of the joint. The *bloom*, as has been indicated above, is remarkably heavy, descending over the joint as a white layer, lightly over the root zone, but only dulling the growth ring. The *growth ring* is light brown in young canes, in older ones green in its upper joints and very dark brown in the lower ones. *Blushing* is not apparent in exposed parts. There is a well marked blackish grey *scar band*, between the bloom layer and the leaf scar. The ivory markings are few and short, usually confined to the upper part of the joint, occasionally passing through the bloom band. Here and there upper joints have massed markings as in *Dhaulu* and *Katha*. The *root zone* is sometimes marked by small brown slits. *Splits* are practically absent but sometimes arise from ivory markings. The *groove* has sometimes the red brown marks composed of fine parallel lines so characteristic of *Katha*.

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Shape viewed medially.—Thickest at leaf-scar and root zone then at growth ring; hence, slightly biconvex; but practically straight-sided.

Shape viewed laterally.—Very slightly zig-zag; traces of swelling below behind, giving the joints occasionally a slight concavo-convexity.

Leaf scar practically horizontal, very occasionally slightly descending, and with a very short *lip*.

Circlet of hairs persistent, strong, brownish below. Occasionally present all the way up, but more often becoming a felt in the upper parts or even disappearing there.

Groove present, shallow, or absent; where present, seen all the way up the joint; occasionally showing the characteristic brown red marks of the *Katha* group.

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Growth ring distinct and not very broad in the specimens examined; its colour referred to above.

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Shooting noted on the average in the three lowest joints in the young canes. *Bursting* usually rather apical, but dorsal in some of the lower joints.

The buds small, rounded, or pointed, usually reaching the growth ring except in a fewer lower joints; if exceeding the growth ring, ovate triangular. Arising at the leaf-scar and without any trace of *cushion*.

Flanges not apparently well developed; *basal patches* present and sometimes regularly formed, white and glistening; *minute black hairs* present, especially below.

8. Leafy shoot.

Five to six leaves in the *terminal tuft*. *Leaf ends* soon angled or bent as in *Katha*.

Number of terminal joints under 2″, 3 in the six months canes and 5 in the ten months.

(*a*) 2·0″, 0·7″, 0·4″, 0·1″.

(*b*) 2·2″, 1·5″, 1·0″, 0·6″, 0·3″, 0·1″, showing the gradual cessation of rapid growth in the older canes.

9. Leaf-sheath.

Length, average longest.—The *average lengths* of the leaf-sheaths in the six canes of (*a*) were 7·2″, 7·4″, 7·7″, 8·4″, 9·0″, 9·4″, 9·8″, 10·3″, 10·8″, 11·1″, 11·1″, 11·3″, 11·1″, 10·9″, 10·6″, 10·2″, 10·2″, (9·9″, 9·6″, 7·0″, 1·8″, 0·3″, 0·1″).

Average longest 11·7″.

The sheaths do not fade to a crushed strawberry colour in the young shoots on dying nor are the edges red brown, as in *Dhaulu*; scarious border is not formed early; silicious spines are absent; the minute *hairs* between the veins behind are just visible with the lens, white above and black below.

Ligule narrow, broadening at middle, with minute hairs on the edge.

Ligular processes distinct, tooth-like in the lower parts but becoming longer in the terminal leaves of the young cane, on one side only.

Proportion of base of lamina to the top of sheath 12 : 17, 12 : 16·5, 14 : 18, showing room for the formation of the ligular process.

10. Lamina.

Width 0·90″—1·05″, averaging about 1 inch.

Length average of six canes measured (*a*) 2′1″, 2′6″, 2′7″, 2′7″, 2′9″, 2′10″, 3′1″, 3′7″, 3′7″, 3′10″, 3′9″, 3′11″, 4′0″, 4′2″, 4′3″, 4′2″, 4′1″, 4′1″, 4′0″, 3′11″, 3′8″, 3′0″, 2′3″.

Average extreme length of leaf in these six canes 4′4″.

Proportion of length to width 50 : 1.

Channelling moderate at base in cut leaves but not noticeable in the field; flattening out soon.

Transverse marks dull, yellow green, bloomed below.

Serrature rather soft and soon disappearing.

DESCRIPTION OF PLATE.

LALRI.

1, 2, 3. Lower, middle and upper portions of a ten months cane. The buds are small, not reaching the growth ring in the lowest joints but reaching or exceeding it higher up. The growth ring is faint in the upper joints but becomes darker below, often darkening at its upper and lower edges first. The circlet of hairs is persistent throughout. The lowest joint of 1 has ivory markings in the root zone.

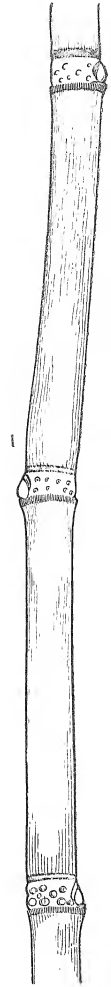
1*a*. The middle bud of 1. Bursting is dorsal; the flanges rise high up and pass broadly round the apex; bristles are few, but the basal patches are distinct.

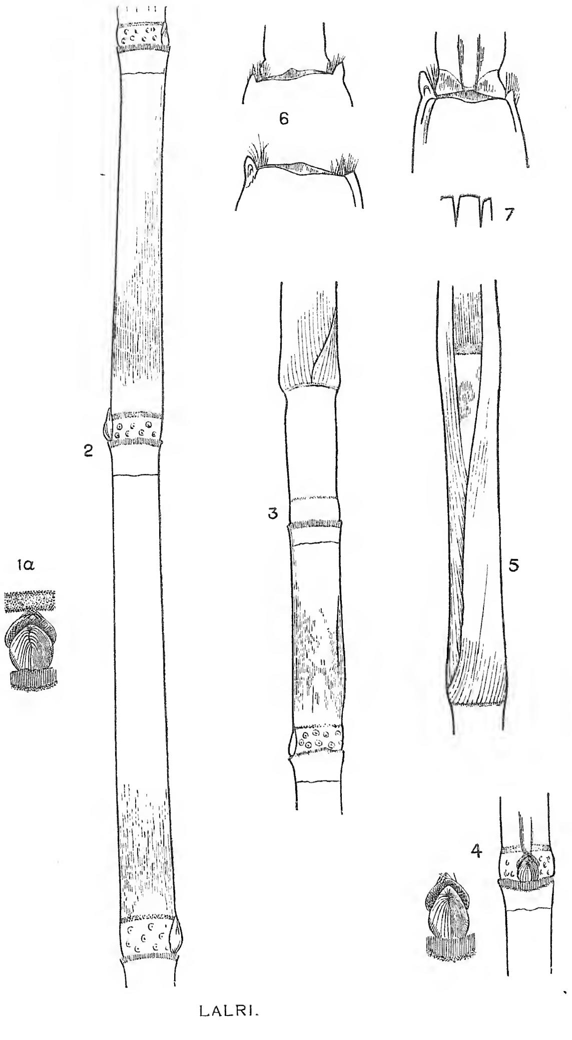
4. A lower node of a six months cane with its bud enlarged. There is a distinct groove. The bud is rather longer than in 1*a* but bursting is markedly dorsal. The scar band is rather broad and distinct.

5. Upper portion of a six months cane. The base of the leaf-sheath clasps the stem widely.

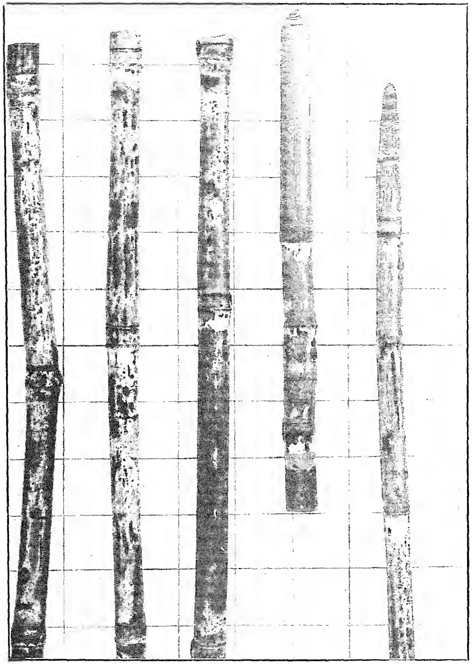
6. The junction of lamina and leaf-sheath in three leaves. Small ligular processes are present, sometimes on both sides.

7. A small portion of the ligule with minute hairs on its edges.





LALRI.



LALRI.-Canes on inch squares.

LALRI. GURDASPUR, 6 Months old.

KANSAR.

1. General remarks as to distribution and agricultural and chemical characters.

A. Kansar is most extensively grown in the submontane tracts, where the water supply and land are specially good. Large areas under this cane are found in canal irrigated land in the Batala Tehsil of the Gurdaspur district, where it is known as *Katha-Kahu.* It is also found in the submontane tehsils of Jullunder and Ludhiana where it is known by the names *Dag Chan* and *Masingen.* It has also been seen as far south as the Chenab Colony but this is exceptional. It dries up and becomes pithy in the centre unless the water supply is very good.

A tall growing, thick red cane of the *Katha* type, approaching *Saretha* in thickness. It requires good land and more abundant water than *Dhaulu of Gurdaspur* or *Phillaur.* It yields very heavily, a good crop giving 40 maunds of *gur* of excellent quality. (*Kansar* is a desi cane with broader leaf than *Dhaulu of Gurdaspur ;* the six months crop was 8-9 feet high. The leaf tips, at first erect, soon become angled as in *Katha*, then quickly curving backwards. The outer canes of a bunch bend outwards a good deal like *Saretha ;* tillering is good. Shooting was present in the six months crop on the farm, the shoots being green, tall, and straight ; rooting occurred to about the fourth joint. The crop on the farm was rather badly smutted.—C. A. B.)

B. A fine cane, not reckoned as hardy as *Lalri* or *Katha ;* yields *gur* on well-land. The variety is classified as semi-resistant to frost. The average composition of the juice (average of the last three years) is :—

Month.	Sucrose %	Invert sugar %
November	14·05	2·71
December	14·95	1·48
January	14·44	1·35
February	14·77	1·32

It is an early ripening cane and is fully ripe about the end of December. The *gur* made from the variety on the farm yielded a sucrose content of 72·31 per cent.

(The details of sections A and B have been kindly furnished by Messrs. Southern and Barnes respectively.)

2. List of specimens examined.

Six months old.—(*a*) Gurdaspur, September 1913. Farm plot, irrigated; 12 canes examined of which six were measured as to joints, leaf-sheaths and laminas. The canes were drawn and the crop photographed.

Ten months old.—(*b*) Gurdaspur, January 1913. Farm plot, irrigated; 25 canes examined of which 20 were measured as to the thickness and length of their joints. The canes were drawn, painted and photographed.

About twelve months old.—(*c*) Gurdaspur, March 1913. Cultivator's field, rainfed; five canes examined, drawn and photographed to scale.

3. General characters of the variety.

Canes practically straight-sided, without prominent nodes, thicker than *Lalri* and much thicker than *Katha* and *Dhaulu*; evidently a *Katha* form. Heavily bloomed, the bloom sometimes blackened. Colour of mature stem vinous, due to the red brown skin under the bloom, but not so strongly marked in the specimens as in *Lalri*. Red brown markings seen in the groove region and the canes smutted in the field. Ivory markings as in *Katha*, not abundant, chiefly in upper parts of the joints and sometimes passing through the bloom band. Growth ring in old joints bright, reddish brown and sharply defined. Circlet of hairs well developed, persistent, of strong parallel hairs, often brownish in colour; a distinct scar band, often with minute black hairs intermingled. Buds small, rounded or polygonal, usually reaching the growth ring, except in the lowest joints. Bursting apparently near the apex,

but not well studied. Hairs on bud moderately developed, the minute black hairs being present or not. Leaves standing out as in *Katha* but much broader, the young tips showing the characteristic bend of *Katha* and *Lalri*. Lamina hardly channelled at the base. Leaf-sheath glabrous, with light coloured edges. Ligular processes as in *Katha*, varying from small to large.

4. Cane measurements.

Dead leaves at six months old.—The six months canes had an average of seven dead leaves.

Length of six months canes after stripping dead leaves.—The canes averaged 2′ 7″, and the shoots 7′ 9″. From this it would appear that *Kansar* does not mature so rapidly as most of the other canes, but it may be that the leaves have a longer period of growth.

Total length of cane and number of joints at six and ten months—

(*a*) six months 63·7″ with 18·5 joints.

(*b*) ten months 64·9″ with 20·0 joints.

Total length of stripped cane divided by average thickness at middle $l \div t$.—(*a*) 103, (*b*) 109.

Length of joints in different parts of the cane, in inches :—

(*a*) average of 6 canes; 2·5, 3·7, 4·1, 4·3, 5·2, 5·4, 4·8, 4·6, 4·8, 4·6, 4·4, 4·1, 3·9, 3·7, 2·5, 1·5, 0·8, 0·3, 0·1.

(*b*) average of 20 canes; 2·5, 3·8, 4·7, 5·3, 5·4, 5·7, 6·0, 5·2, 4·7, 3·9, 3·6, 3·2, 3·1, 2·8, 1·9, 1·4, 0·8, 0·5, 0·3, 0·1.

(*c*) The joints were usually longest about one-third of the way up.

The same tendencies are noticeable in this, as in other varieties, for the canes from older plots to have longer joints, especially at the base, and for their terminal joints to decrease in length less rapidly, facts which are more fully dealt with elsewhere.

Thickness of the cane at various points.—The canes of *Kansar* are usually fairly uniform in thickness all the way up. Sometimes there are a few narrow joints at the very base, succeeded by others

thicker than those in the middle, and this, although not shown in the figures, indicates a slight narrowing upwards. In other cases the youngest, immature joints at the top are swollen and barrelled. Average of 20 canes (*b*) base 0·56″; middle 0·59″; top mature 0·58″.

5. Colour of cane.

The colour of *Kansar* is rather difficult to describe. It is a heavily bloomed cane and the thickness of this layer has a very great effect on the colour, and the bloom is heaviest in the mature joints. There is a white bloom band heavily descending and often a good deal dulled by blackening. The mature joint becomes vinous above because of a brown skin beneath the bloom, further up the cane there are pinkish streaks and blotches below the bloom band and, ultimately, the joints are yellow or green with pink markings. The youngest joints have less bloom and are at first apple green, then glaucous green or yellow, often with brown blotches.

The *growth ring* is olive green in the youngest parts, becoming light brown and ultimately a bright, reddish brown and very sharply defined.

The *root zone* is heavily bloomed, usually of a light cream colour, but becoming bone yellow and sometimes blackened below.

There is sometimes a good deal of *blackening* of the joints, especially on the upper parts of the lower ones. The joints do not *blush* on exposure to light between the gaping leaf-sheaths.

Below the leaf scar there is no definite sharp dark line, but a diffused grey to blackish grey zone between the scar and the bloom band. This is a typical *scar band* and there are often minute black hairs present in it.

The *groove* has the red mark so characteristic of *Katha*, seen under the lens to be composed of minute, parallel red brown lines; cases of black incrustation have also been met with.

The *ivory markings* are present, although not abundant, usually in the upper parts of joints and changing into splits. They

sometimes penetrate the bloom band and are present occasionally in the root zone. Here, as in *Katha* and other canes, an occasional joint near the top is seen to be covered by ivory markings close together in the middle of the joint, reminding of the markings typical of *Tereru*. These often change into splits.

6. Character of the joint.

Thickness, ovalness in section.

Kansar is a thick cane as far as those in the Punjab are concerned. It is thicker than *Katha* and *Dhaulu* and, in the field, than *Lalri*. The average thickness in the middle was as follows :—

(*a*) Six canes 0·58″ to 0·65″; average 0·62″.
(*b*) Twenty canes 0·48″ to 0·59″; average 0·59″.
(*c*) Five canes, thickest 0·68″; thinnest 0·55″.

Ovalness is not usually marked, lateral and medial measurements being :—

(*b*) bottom of cane 0·56″ + 0·58″;
middle of cane 0·59″ + 0·61″;
top of cane 0·58″ + 0·60″;
(*c*) thickest cane 0·68″ + 0·68″; thinnest 0·55″ + 0·61″.

Length of the mature joints.—The canes examined had tolerably long joints, the extremes being 3 to 8 inches.

(*a*) of 6 canes, shortest (basal) 2·5″; average longest 5·6″; average mature 4·2″.
(*b*) of 20 canes, shortest (basal) 2·5″; average longest 6·0″, average mature 4·5″.
(*c*) the joints varied from 4 to 8 inches in length.

Shape viewed medially.—Thickest at leaf scar and root zone; growth ring often rather low and the rest practically straight. This gives the lower part of the joint a slight tendency to narrow upwards.

Shape viewed laterally.—There is sometimes a slight swelling below behind which gives the cane a slightly concavo-convex appearance. The joints are, however, practically straight.

Leaf scars not appreciably or very slightly descending and without a definite *lip*.

Circlet of hairs well developed, present in all joints, of strong, straight, parallel hairs, often discoloured.

Scar band present, distinct, often with minute black hairs.

Groove present, indicated or absent, often a flattened place, with the red brown marks of *Katha* and sometimes the harsh black incrustations.

Root zone moderately broad, usually not swollen, covered with bloom, sometimes with ivory markings; with 2-3 rows of eyes. Occasionally slightly tubercled, especially below.

Growth ring not very broad or pronounced. In old canes sometimes rather prominent, because of the dark brown colour; but more usually of a light brown tint and flattened.

7. Bud.

The buds of *Kansar* were found to be *shooting* in the six months' crop, but not in the others examined. To all appearance the *bursting* of the buds is more or less apical, except in a few lower joints where it is dorsal.

They are small, rounded or polygonal, usually reaching the growth ring, but sometimes falling short of it in the lowest joints; they usually arise at the leaf scar.

The *flanges* are rather well developed and arise at or slightly above the middle and pass round the apex.

The *bristles* are moderately developed, the *basal patches* well shown, of white glistening parallel hairs, and the *minute black hairs* present or not.

8. Leafy shoot.

The leaves are rather widely separated on the stem and stand out much as in *Katha*; the leaf ends are erect, but some soon show the characteristic bend of *Katha*.

Number of terminal joints under 2″, four in the six months canes and six in the ten months.

(*a*) 2·5″, 1·5″, 0·8″, 0·3″, 0·1″.

(*b*) 2·8″, 1·9″, 1·4″, 0·8″, 0·5″, 0·3″, 0·1″.

9. Leaf-sheath.

Length, average longest.

Average of the six months canes in inches, 7·9, 9·2, 10·3, 11·5, 11·9, 12·0, 12·0, 12·0, 12·3, 11·9, 11·6, 11·2, 11·1, 11·0, 10·9, 10·7, 10·7, (9·7, 7·3, 2·2, 0·4, 0·1).

Average longest 11·3.

The dying sheaths do not fade to a crushed strawberry as in *Dhaulu* and the sheaths are little bloomed. The *edges* of the young leaf-sheaths are light coloured as in *Katha*. *Silicious spines* are absent and the *hairs* between the veins behind are distinctly visible under the lens, white above and black below. Bases of sheaths *clasping* the stem rather widely.

Proportion of base of lamina to top of sheath, 14 : 19 and 14 : 20, in two canes.

The *ligular processes* vary, they are often large and on one side only.

Ligule narrow, with minute hairs along the edge.

10. Lamina.

Average *width* 1·0″ to 1·3″.

Length, average in six; six months canes, 1′9″, 2′4″, 3′2″, 3′2,″ 3′2″, 3′6″, 3′10″, 3′11″, 3′9″, 3′11″, 4′1″, 4′1″, 4′1″, 4′0″, 4′1″, 4′2″ 4′2″, 4′3″, 4′3″, 3′11″, 3′2″, 2′4″, *average longest* 4′4″.

Proportion of length to width, 40 : 1.

Hardly *channelled* at base in the field, although seen to be so in the specimens in the laboratory. *Transverse marks* yellowish green, soon bloomed and dulled below. *Serrature* strong in young leaves, soon disappearing, except at the tips.

DESCRIPTION OF PLATE.

KANSAR.

1, 2. A lower and a middle portion of a ten months cane. The buds (6, 7, 8, 9) are shorter in the lower joints and do not there reach the growth ring. The circlet of hairs is strong and persistent. Ivory markings are present on the root zone at the base, of 1.

3. Lamina and sheath at their junction, showing a distinct, though short ligular process.

4. A portion of the ligule with a fringe of minute hairs on its edge.

5. An uppermost joint showing the base of the leaf-sheath widely clasping the stem ; the circlet of hairs is still present.

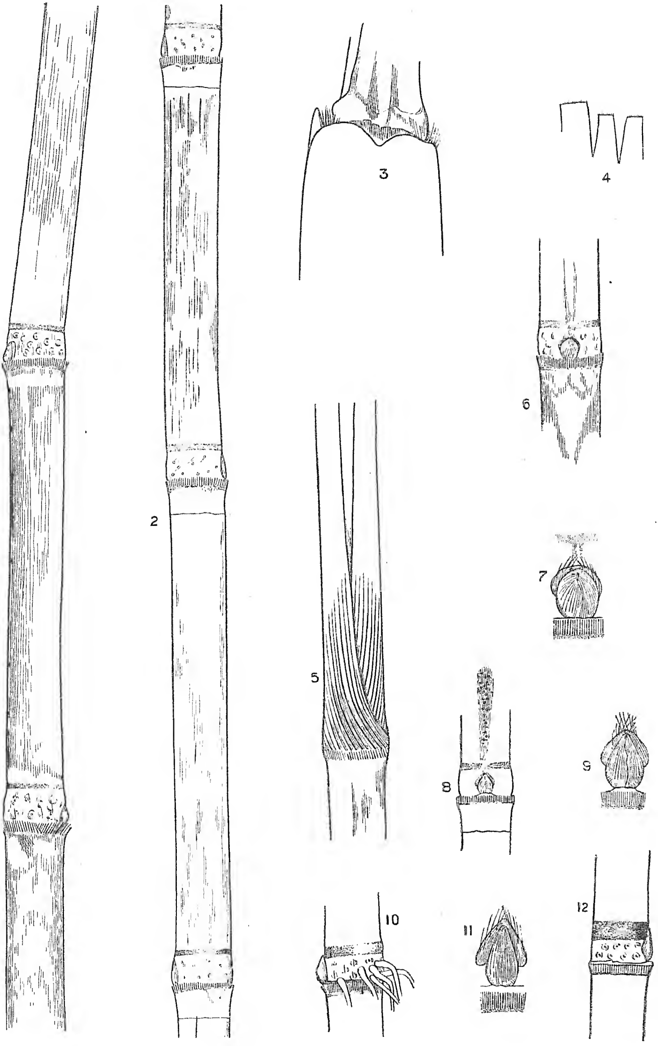
6, 7. The upper node of 1 showing the medial view and the enlarged bud. The bud is short and does not reach the growth ring.

8, 9. The middle joint of 2. The bud is longer, has well defined basal patches and there is a black incrustation in the groove above the bud.

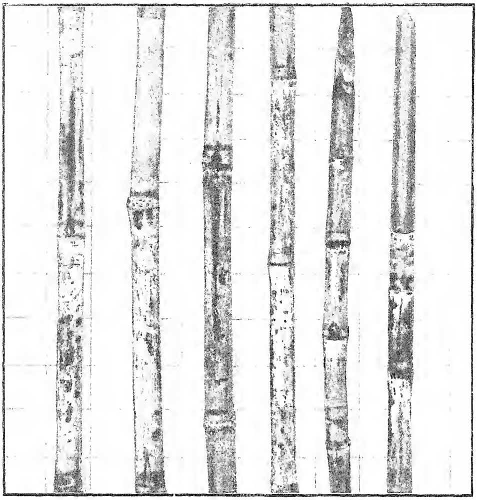
10. A lower joint of another cane, showing the roots emerging and a very well developed dark brown growth ring. There are ivory markings, on the root zone. The bud reaches the growth ring.

11. Another joint with very broad growth ring and rather elongated bud. The scar band is well shown in this and most of the other figures.

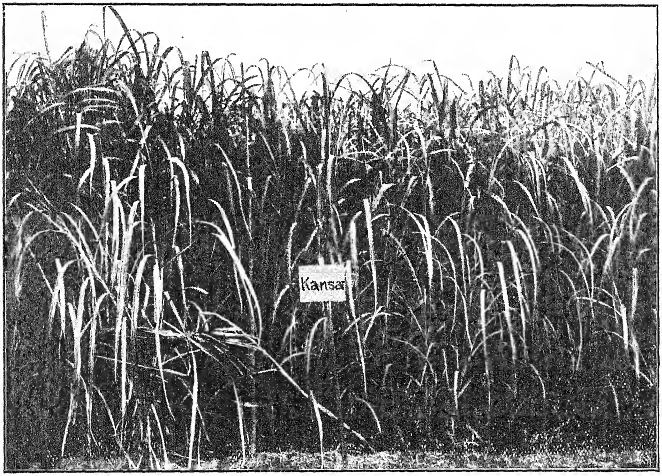
PLATE VI.



KANSAR.



KANSAR. GURDASPUR
(The lines are one inch apart.)



KANSAR, GURDASPUR, 6 MONTHS OLD,
(The white mark on the bamboo is just under 6 feet.)

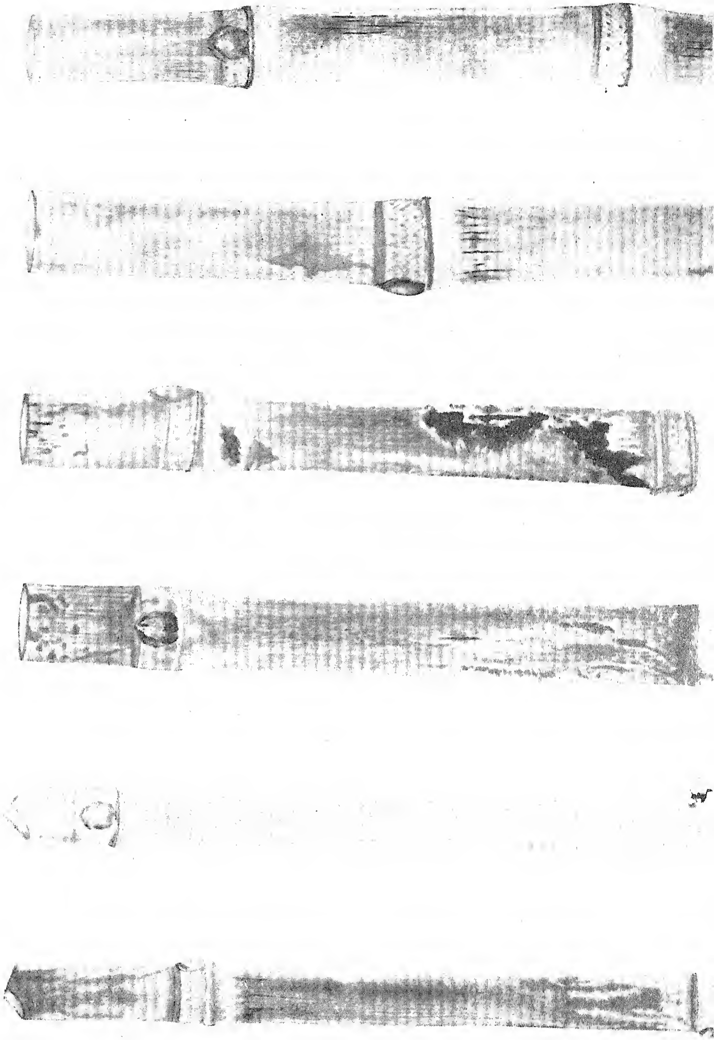
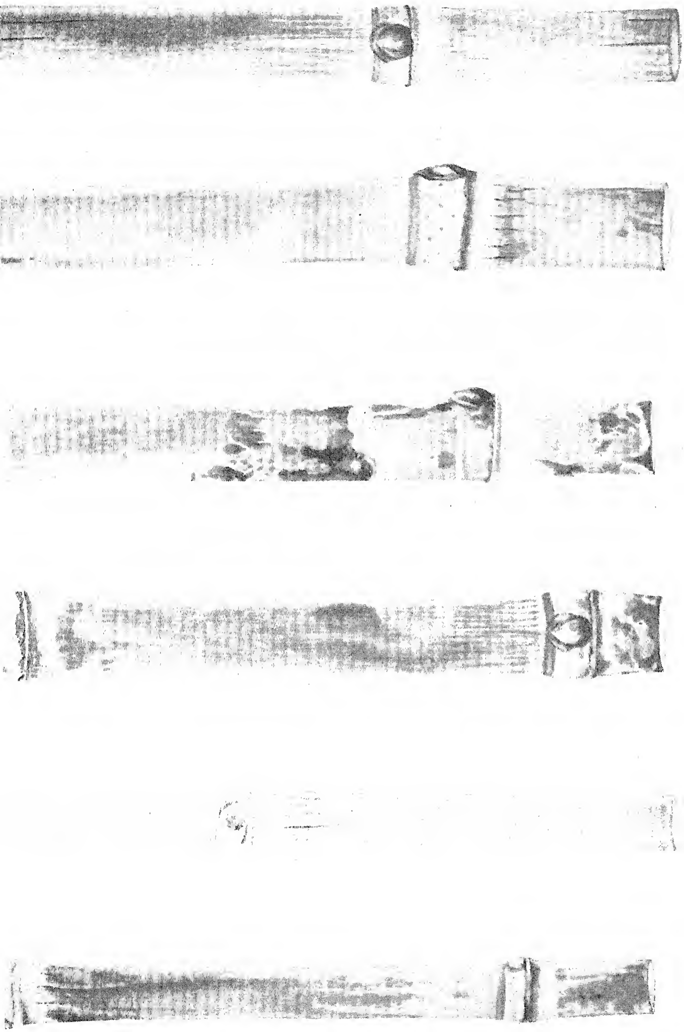


PLATE VIII.



KANSAR

LALRI

KATHA

DHAULU OF GURDASPUR.

1. General remarks on distribution and agricultural and chemical characters.

A. This variety is confined to irrigated land in Gurdaspur and adjoining districts. Outside of that tract it is seldom found and does not appear to thrive anywhere as well as in the Gurdaspur district. It is occasionally found, as is also *Tereru*, in Jullunder, Ludhiana and Ambala districts as a mixture in crops of *Dhaulu of Phillaur*. The two Gurdaspur kinds are not distinguished then and both are classed as *Ghorru* and are disliked as they are said to yield very inferior juice.

Dhaulu of Gurdaspur is green when unripe and becomes white later, as is indicated by its name. It is thicker than *Katha* and requires better soil and a more liberal supply of water. It is occasionally found under *barani* conditions but is nearly always irrigated. It ripens later than *Katha ;* the leaves are more easily stripped and the rind is softer. The sets at planting time are more liable to be attacked by white-ants. This applies to all the kinds grown, *Katha* being the most resistant ; the thicker the cane the more readily is it attacked. The *gur* is of a better colour and the sugar whiter than in *Katha*, but the *gur* is said not to keep so well. (The six months canes were 9-10 feet high at Gurdaspur and the ten months higher still. The canes were erect, in bunches, often covering the ground thickly, but falling at the edges of the field or where the growth was very luxuriant, then often being crooked and lying down. The older leaves stand out from the stem as in *Katha*. Tillering is very good but depends on the closeness of planting and evenness of germination. Where thinly planted very large numbers of shoots have been noted rising from one stool. I should call the young canes glaucous green and the old, fully ripe ones, clear

bone yellow but the term white is often applied as distinguishing yellow canes from green. Rooting occurred at from two to four of the lowest joints, but was not marked; shooting was rare in the specimens examined. The plants were only slightly attacked by smut, which seems to be rather typically present in the *Katha* alliance, but a good deal of *Fomes lucidus* was found in places. As indicated below, *Dhaulu of Gurdaspur* closely resembles *Katha* but is distinguished by a large number of minute differences, which would hardly have been studied but for the closeness of the two canes. It would seem that *Dhaulu* may be a colour variety, more delicate and therefore adapted to more generous treatment. The canes examined were chiefly those grown on the Gurdaspur Farm or obtained in its neighbourhood. Since my last visit Mr. Southern has drawn attention to the fact that this cane does not agree with that under the same name further west, and some canes of the latter sent down have been separated under the name *Dhaulu of Phillaur*.—C. A. B.)

B. A fine soft cane yielding *shakkar* on good soils. The variety is classified as "quickly affected by frost but quickly recovering." The average composition of the juice (average of the last three years) is :—

Month.	Sucrose %	Invert sugar %
November	12·21	2·51
December	13·00	1·48
January	14·44	1·34
February	15·70	0·66

It is fully ripe about the end of January. The *gur* or *shakkar* made from various specimens of the variety yielded a sucrose content from 67·62 per cent. to 76·0 per cent.

(The details of sections A and B, have been kindly furnished by Messrs. Southern and Barnes, respectively).

2. List of specimens examined.

Young canes—Six months old. (*a*) Gurdaspur, September 1913. Irrigated farm plot (canes from Bham); six canes examined and

six others measured as to length of joint, leaf-sheath, and lamina; canes drawn and photographed to scale, leaf parts drawn, crop photographed.

Mature canes ten months old. (*b*) Gurdaspur, January 1914. Irrigated farm crop (local canes); 25 canes examined of which 20 were measured as to thickness and length of joint; five others selected for drawing, painting, and photographing to scale; crop photographed.

Mature canes twelve months old. (*c*) Gurdaspur, March 1913. From a cultivator's field; six canes examined, drawn and photographed to scale; habit photographs taken in the field.

(*d*) Harchowal, March 1913. Cultivator's field; canes examined and photographed to scale.

Besides these, 18 canes were obtained in September 1913, from Jullunder. These were examined and the canes drawn, but there were puzzling differences noted at the time, and it now seems probable that the canes were examples of the more eastern *Dhaulu of Phillaur*. They are not, therefore, included in this description.

3. General characters of the variety.

Dhaulu of Gurdaspur is a taller and thicker cane than *Katha* of the same district, and the leaves are broader and of a fresher green. It is usually an irrigated crop, which limits its region, and is more delicate than *Katha* against frost. The canes are thin, straight-sided, the nodes, perhaps, a little more prominent than in *Katha*. The colour of the stem is glaucous grey or green in young parts to clear bone yellow in older. The stem blushes readily on exposure to a vinous or purple, with brown skin under the bloom and, on being cut and stripped, turns a red pink in a few days. The characteristic red brown marks in the groove of *Katha* are absent in *Dhaulu*. Ivory markings are not uncommon but the canes vary, from practically none, to so many that a separate variety (*Tereru*) has been instituted by the cultivators. These ivory markings are usually confined to the upper two-thirds of the joint and do not penetrate

the bloom band. There is usually a definite brown scar line as contrasted with the scar band of *Katha*. The growth ring is distinct, light brown in older joints. The circlet of hairs is usually present in the lower joints but soon disappears upwards, especially under the bud, or changes to a felt of small hairs. The buds are similar to those in *Katha*, small, but reaching the growth ring; they usually burst, however, more or less apically and appear to be rather better provided with hairs; minute black hairs are generally present. The leaf-sheaths turn crushed strawberry colour on death in the six months canes and blush readily in the ten months canes, while their young edges soon turn red brown,—all of them characters distinguishing *Dhaulu* from *Katha*. The tips of the leaves do not bend sharply as in canes of the *Katha* alliance. The sheath does not clasp the stem broadly and ligular processes are absent or small.

4. Cane measurements.

Dead leaves at six months old, usually 14-15.

Length of six months canes after stripping dead leaves, the canes averaged 4′9″ and the shoots 5′9″.

Total length of cane and number of joints at six and ten months—

(*a*) Six months old canes 72·8″, with 25 joints;

(*b*) Ten months old cane 69·4″, with 27 joints.

It is to be noted that (*a*) and (*b*), were not drawn from the same plot as was the case in all other varieties, and this may account for the fact of the six months old canes being longer. None the less, it is evident that most of the growth here, as in *Katha*, has already taken place by the end of September.

Total length of stripped cane divided by average thickness at middle, $l \div t$.

(*a*) 142 (*b*) 142.

Length of joints in different parts of the cane, in inches :—

(*a*) 1·7, 2·3, 2·7, 2·9, 3·3, 3·6, 4·0, 4·5, 4·7, 4·8, 4·9, 4·6, 4·1, 3·5, 3·7, 3·7, 3·1, 2·7, 2·4, 2·2, 1·8, 1·2, 0·6, 0·4, 0·1.

(*b*) 1·7, 2·3, 3·1, 3·3, 3·7, 3·9, 4·0, 4·1, 3·9, 3·7, 3·5, 3·5, 3·5, 3·3, 3·1, 2·9, 2·7, 2·4, 2·4, 2·1, 1·8, 1·4, 0·9, 0·8, 0·5, 0·2, 0·1.

There is little difference between these curves, excepting that the older canes show a slower rate of growth at the tip, as might be expected. The comparison in the curves, made in *Katha* and other canes, does not hold here and perhaps is due to the fact that the canes were not taken from the same plot in the two cases.

Thickness of the cane at various points.—In thickness the canes were fairly uniform all the way up, with a slight tendency to narrowing upwards.

Average thickness of 20 mature canes ten months old:—

(*b*) Bottom joint 0·50″; middle 0·48″; top mature 0·46″. The maturer canes of this series of 20 tend to become thinner upwards, while those that are less mature tend to thicken upwards.

5. Colour of cane.

The canes in *Dhaulu* are glaucous green or greyish green when young, becoming clear bone yellow as they mature and *blush* dark vinous purple where exposed by the separation of the leaf-sheaths, the skin below this blush being clear light brown. There is sometimes a slight amount of *blackening*, especially in the upper part of the joint. The stems, after cutting, become a reddish pink which is very striking, those of *Katha* cut at the same time not or only very slightly assuming this colour. The youngest joints near the apex are clear apple green.

The *bloom band* is well seen in young canes or parts, but hardly forms a distinct band; it descends as far as the growth ring and covers the root zone heavily. The presence of the bloom changes the light green of the skin to a greyish glaucous green. The *growth ring* is light brown and distinct, becoming brownish yellow and ultimately green as one proceeds upwards to the young joints. The *root zone* is light straw coloured in mature joints, and cream coloured with heavy bloom in young ones. The *groove* does not

show the red brown marks so characteristic of *Katha*, but the harsh black incrustation has been occasionally noted.

Ivory markings are not uncommon in *Dhaulu*, but the canes vary considerably in this respect. As stated above, certain ryots attribute the abundance of these markings in *Tereru* to drought conditions, while others separate the heavily marked ones from *Dhaulu* under this name. The typical markings in *Dhaulu* are a series of parallel lines in the middle or upper part of the joint, not passing through the bloom band. They are not usually present in the root zone as in *Katha*.

There is a distinct *scar line* in *Dhaulu* of a brownish colour in old joints below the edge of the leaf-scar, but this is less definite in younger joints.

6. Character of the Joint.

Thickness, ovalness.—*Dhaulu* has thicker canes than *Katha*, but they are still very thin. As will be seen from the figures, the farm canes seem to be thinner than those taken from the ryots' field :—

(*a*) of 12 canes six months old, the average was 0·50″;

(*b*) of 20 canes ten months old, the average was 0·46″ (0·37″ to 0·57″);

(*c*) of 6 canes twelve months old, thickest 0·56″, thinnest 0·45″;

(*d*) of 6 canes twelve months old, thickest 0·62″, thinnest 0·46″.

Dhaulu has a distinct tendency towards *ovalness ;* thickness, lateral + medial :—

(*b*) bottom of cane 0·50″+0·54″;
middle ,, 0·46″+0·49″;
top mature 0·46″+0·52″;

(*c*) thickest cane 0·62″+0·66″, thinnest 0·45″+0·47″;

(*d*) thickest cane 0·56″+0·60″, thinnest 0·46″+0·52.″

Length of mature joints—*Dhaulu* on the whole has shorter joints than *Katha*, and this is emphasised by their greater thickness—

(*a*) average length 3·4″; average shortest 1·7″; average longest 5·1″;

(*b*) average length 3·1″; average shortest 1·7″; average longest 4·5″;

(*c*) the joints of six canes were judged to be 3″ to 5″ long;

(*d*) the joints of four canes were judged to be 2·5″ to 4·5″ long.

Shape viewed medially.—Thickest at leaf-scar, or at growth ring when that is swollen, narrowing towards the middle, hence, generally biconcave. This is seen especially in the shorter joints. The root zone usually narrows downwards, but is often swollen in the lower joints. The nodes are more marked than in *Katha*.

Shape viewed laterally.—Practically straight-sided and uniform. In some joints there is a distinct slight swelling below behind, but this is totally absent in others. A few canes have been met with which are distinctly zigzag.

Leaf-scar practically horizontal and without a definite *lip*. No descending *leaf-scar end*.

Circlet of hairs usually present in the lower joints but, passing upwards, it rapidly disappears, especially under the buds. It frequently changes early into a felt of hairs before disappearing.

Splitting does not appear to be very common; where noted, the splits were black in colour and obviously arose from ivory markings.

Groove often present as a flattened area, but never pronounced. Sometimes it has the black incrustation but not the red brown marks of *Katha*.

Root zone not very broad, narrowing downwards except in the lower joints. With 2-3 rows of rather distinct eyes, not tubercled except in the lower joints.

Growth ring distinct, with definite upper and lower boundary, hereby differing from *Dhaulu of Phillaur*. Narrow and flat or broad and raised; the latter was noted especially in the six months old canes where the growth ring was sometimes $\frac{1}{4}$″ wide and distinctly swollen.

7. Bud.

The buds examined were in no cases *shooting*. *Bursting* takes place high up, at or near the apex.

The buds are small to moderate in size, reaching the growth ring, ovate, pointed, sometimes broader than long at the base of the stem, but becoming narrower upwards and sometimes diamond shaped.

They usually rise at the leaf-scar but occasionally some have been seen rising a little above it ; no *cushion* was however seen.

The *flanges* are moderately developed and sometimes rather broad, rising below the middle and passing round the apex to a wide angle. They are often dark-coloured.

Bristles moderately developed of sparse, stiff hairs round the border of the flanges ; a tuft of silky hairs usually present at the place where the base of the flange meets the bud, on each side. The *basal patches* present, often ascending the veins of the bud and passing into the tuft of hairs. *Minute black hairs* far commoner than in *Katha*, chiefly in the basal patches and round the base of the bud.

8. Leafy shoot.

There are 5-7 leaves in the *terminal tuft* (the last two inches of the visible shoot).

Leaf end not angled or bent as in *Katha*.

Number of terminal joints under 2″, 5 in six months canes and 7 in the ten months :—

(*a*) 2·2″, 1·8″, 1·2″, 0·6″, 0·4″, 0·1″.
(*b*) 2·1″, 1·8″, 1·4″, 0·9″, 0·8″, 0·5″, 0·2″, 0·1″.

9. Leaf-sheath.

Length, average longest of leaf-sheaths in the six canes :—

(*a*) 7·9″, 8·1″, 8·8″, 9·1″, 9·2″, 9·3″, 9·5″, 9·6″, 9·8″, 9·9″, 10·3″, 10·7″, 10·5″, 10·3″, 9·9″, 10·2″, 10·3″, 10·5″, 10·4″, 10·2″, 9·8″, 9·3″, 8·9″ (8·9″, 8·5″, 5·4″, 0·9″, 0·1″),

average longest 11·0″.

The leaf-sheaths are more easy to detach than in *Katha*, but the base breaks off and is difficult to remove.

Not or very slightly bloomed. The sheaths of the six months old canes turned a clear crushed strawberry colour immediately after death, then changing to a dull straw colour. The sheaths in the mature (10 months) canes, on the other hand, did not turn crushed strawberry but usually blushed deep red while living, especially the younger ones near the apex. These colorations were absent in *Katha*. The *scarious border* commences high up and before the death of the lamina edge. The *edges* of the young leaf-sheath soon become bright red brown.

The sheath is rough dorsally with a few *silicious spines*. The minute hairs between the veins behind are, as in *Katha*, puberulous and hardly distinct under a lens.

The hairs at the top of the sheath often *descend along the edges* for a short distance. The base of the sheath *clasps* the stem less widely than in *Katha*, only surrounding the circumference $1\frac{1}{4}$ times. The outer edge of the leaf sheath can be seen when viewing the shoot medially.

Proportion of base of lamina to top of leaf sheath, 0·65″ to 1·00″. In other cases the proportion was 13:16, 13:17, 14:16, figures showing a marked difference from those in *Katha*.

The *ligular processes* are consequently hardly present, sometimes small or indicated, never long as in *Katha*.

The *ligule* is rather narrow, but widens in the middle; the edges are covered as in *Katha* with minute hairs.

10. LAMINA.

Width 1·1″ to 1·3″.

Length in six months canes, averages from base upwards, 2′1″, 2′8″, 2′6″, 2′8″, 2′10″, 3′0″, 3′1″, 3′2″, 3′3″, 3′5″, 3′7″, 3′7″, 3′9″, 3′9″, 3′7″, 3′7″, 3′7″, 3′8″, 3′9″, 3′10″, 3′10″, 3′10″, 3′9″, 3′8″, 3′6″, 3′2″, 2′5″.

Longest 3′11″, 4′1″, 4′1″, 4′1″, 4′1″, 3′11″, average 4′0″.

Proportion of length to width, 37 to 1.

Not markedly *channelled* at the base and soon flattening out.

Transverse marks slightly blackish green and slightly bloomed; the leaves lighter green than in *Katha*.

Serrature rather soft, persistent.

Proportional width of midrib to lamina.—At 1″ from base, 18 : 100; at 6″, 20 : 100; at 12″, 15 : 100. The midrib is proportionately narrower than in *Katha*.

TERU OR TERERU.

1. General remarks on distribution and agricultural and chemical characters.

A. This cane is very like *Dhaulu of Gurdaspur* but with ivory markings. In Gurdaspur district, where it is commonly found mixed with the local *Dhaulu*, it is looked upon as a fairly good quality cane and the presence or absence of ivory markings is said to be a question of weather conditions. Sometimes a crop from typical *Teru* seed will, in the next year, show no ivory markings, it is said. On the whole *Dhaulu* is preferred to *Teru* in the Gurdaspur district. In parts of Jullunder, Ludhiana and Ambala districts it is occasionally met with as a mixture in the *Dhaulu of Phillaur* crops. Generally then the ivory markings are present but occasionally they are absent and then the cane is identical with the *Dhaulu of Gurdaspur*. In both cases the cane is known as *Ekkar* or *Ghorru* and is much disliked, as it is said to yield very inferior juice and the better cultivators discard it when selecting cuttings for seed. In the Samrala Tehsil of Ludhiana district the ivory markings are sometimes very heavy indeed. (There appears to be no real morphological difference between *Tereru* and *Dhaulu of Gurdaspur*. The name signifies, I am told, a streak, and the cane is distinguished by the greater number of ivory markings which it shows on the stem. These markings are however explained in different ways by the cultivators. Some state, as noted already, that their presence indicates a condition of drought, while others steadfastly adhere to the opinion that *Tereru* is a different cane from *Dhaulu*. It appears to me that the specimens which were brought to me were sought out for their abundance of ivory markings and I suspect that they were drawn equally from *Dhaulu* and *Tereru* plots. That the markings are not constant is, I think, shown by the fact that

6

of the 20 canes examined at Gurdaspur, sown from typical *Tereru* cuttings only seven had the markings at all in evidence. It was also found quite possible to obtain typical *Tereru* canes from the *Dhaulu* plot. After a careful morphological study, no intrinsic difference was found between the two canes. Taking these facts into consideration it was deemed unnecessary to detail a full description of this cane from the accumulated notes. The measurements are however given as these do not altogether agree with one another nor with those given for *Dhaulu*. Further study may show that these two canes represent different conditions and such are likely to be evidenced by the growth of the canes.—(C. A. B.)

B. A soft cane generally yielding *shakkar* on good soils. The variety is classified as semi-resistant to frost on the results of the last three years' experiments. The average composition of the juice (average of the last three years) is :—

Month.	Sucrose %	Invert Sugar %
November	13·32	1·37
December	13·84	1·48
January	14·24	1·14
February	16·99	0·71

The variety ripens late in February. The sample of *gur* made from it on the Agricultural Station at Gurdaspur yielded 68·15 per cent. of sucrose.

(For the details of sections A and B, I am indebted to Messrs. Southern and Barnes respectively).

2. List of specimens examined.

Canes about six months old.

(*a*) Gurdaspur, September 1913. Farm plot, irrigated ; 12 canes examined of which six were measured as to joint, leaf-sheath and lamina. The canes were drawn and the plot photographed.

Canes about ten months old.

(*b*) Gurdaspur, January 1914. Farm plot, irrigated ; 25 canes examined of which the joints were carefully measured in 20. The

canes were drawn and photographed to scale, a typical joint was painted and the field was photographed.

Canes about twelve months old.

(*c*) Gurdaspur, March 1913. Cultivator's field, rainfed; 7 canes were examined and photographed to scale.

(*d*) Harchowal, March 1913. Cultivator's field; 6 canes were drawn and photographed to scale.

3. General characters of the variety.

These have been mentioned above and the differences from *Dhaulu* discussed.

4. Cane measurements.

Number of dead leaves at six months old, 10 to 15, averaging 13.

Length of cane and shoot after stripping these: cane 3′3″, shoot 6′7″.

Total length of cane and number of joints at six and ten months.

(*a*) Total length 66·1″, number of joints 24.
(*b*) Total length 70·6″, number of joints 24.

Total length divided by average thickness at the middle, $l \div t$,
(*a*) 130, (*b*) 150.

Length of joints in different parts of the cane, in inches:—

(*a*) 1·0, 1·5, 1·9, 2·2, 2·7, 3·3, 3·8, 4·0, 4·2, 4·1, 3·8, 3·7, 3·5, 3·4, 3·7, 3·5, 3·5, 3·2, 2·7, 2·2, 1·3, 0·6, 0·3, 0·1.

(*b*) 3·1, 3·6, 4·1, 4·6, 4·5, 4·4, 4·2, 4·2, 4·4, 4·3, 4·0, 3·9, 3·8, 3·4, 3·1, 3·1, 2·8, 2·2, 1·6, 1·0, 0·7, 0·5, 0·3, 0·1.

Here, as in *Katha*, the curves of the six months and ten months canes differ very considerably, the older canes showing much longer joints near the base and shorter ones near the apex.

Thickness of the cane at various points.

(*b*) Average of 20 canes, base 0·47″, middle 0·45″, top mature 0·46″. These differences are immaterial and the cane appears to be of practically the same thickness all the way up. It is to be

noted however that these measurements are of mature joints and that the youngest, immature joints at the top, were often swollen and barrelled.

6. Character of the joint.

Thickness, ovalness.

(*a*) Twelve canes measured at the middle; thinnest 0·45″, thickest 0·60″, averaging 0·50″

(*b*) Twenty canes measured laterally + medially :—

base 0·47″+0·50″, middle 0·45″+0·48″, top mature 0·46″+0·50″.

From these measurements *ovalness* is not a marked character.

(*c*) Seven canes, thickest 0·54″+0·58″ thinnest 0·44″+0·46″.

(*d*) Six canes, do. 0·58″+0·61″ do. 0·50″+0·52″.

Length of mature joints.

(*a*) Six canes, average length 3·1″, average longest 4·4″, average basal 1·0″.

(*b*) Twenty canes, average length 3·7″, average longest 4·8″, average basal 3·1″.

(*c*) Seven canes, joints judged to be 3″ to 5″ long.

(*d*) Six canes, joints 2·5 ″ to 4·0″ long.

9. Leaf-sheath.

(*a*) Six months canes; average longest 10·2″; averages of the six canes in inches :—

7·4, 7·6, 7·9, 8·1, 8·0, 8·4, 8·6, 8·7, 8·9, 9·4, 9·6, 9·9, 10·1, 10·1, 9·9, 9·7, 9·3, 9·4, 9·7, 9·7, 9·4, 9·4, 9·2 (8·7, 7·8, 3·2, 0·7, 0·1).

10. Lamina.

Width 1·0 to 1·2″.

Length—Average lengths of the leaves from base to apex:—1′11″, 2′1″, 2′5″, 2′5″, 2′7″, 2′8″, 2′9″, 2′11″, 3′1″, 3′3″, 3′5″, 3′5″, 3′6″, 3′8″, 3′7″, 3′8″, 3′7″, 3′6″, 3′6″, 3′7″, 3′6″, 3′7″, 3′5″, 3′3″, 2′7″, 2′2″.

Average longest lamina, 3′9″.

Proportion of length to width 37·5 : 1.

DESCRIPTION OF PLATE.

DHAULU OF GURDASPUR, TERERU.

1. A six months cane with rather broad growth rings taking part in the curvature of the cane.

2. A ten months cane, slightly zigzag; the circlet of hairs is absent and a distinct scar line is seen below the dark leaf scar.

3. Lamina and sheath at their junction. There is no ligular process.

4. A portion of the ligule with a fringe of minute hairs on its edge.

5, 6. The middle joint of 1 with its bud enlarged. There are few bristles in the latter, but there is a slight cushion below the bud. The circlet of hairs is not present but the top of the leaf scar bears a series of parallel grooves.

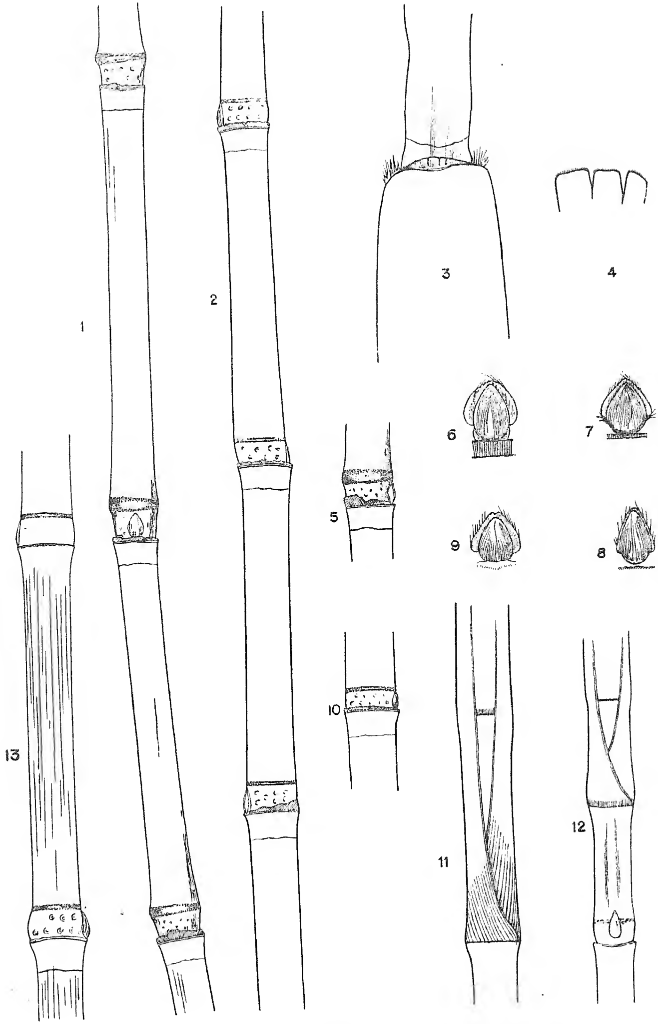
7. Another bud of the same cane with tufts of hairs at the bases of the flanges. In 6 and 7 minute black hairs are seen at the base of the bud.

8. A bud from a young, upper joint, more elongated than usual and rising slightly above the leaf scar.

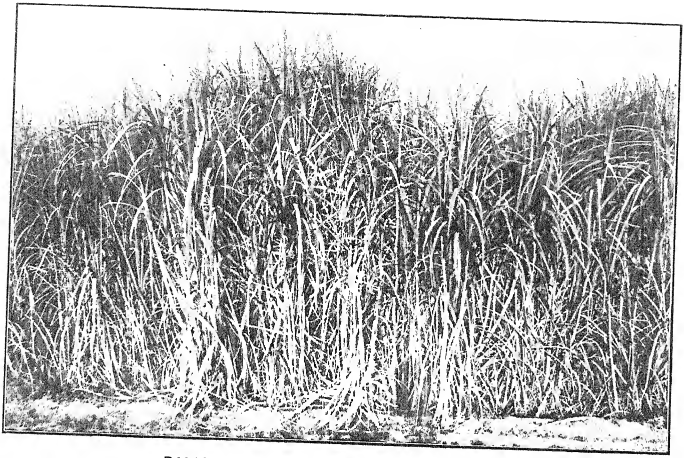
9, 10. A lower joint of cane 2 with narrow root zone. Its bud shows apical bursting.

11, 12. Upper joints of cane with base of leaf sheath clasping the stem round one and a quarter times its circumference. In 12 the bud is elongated and rises a good deal above the leaf scar.

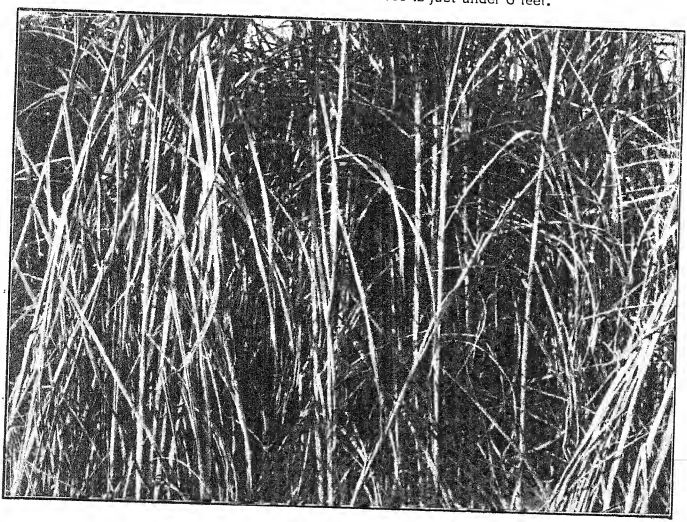
13. A joint of *Tereru* with characteristic ivory markings.



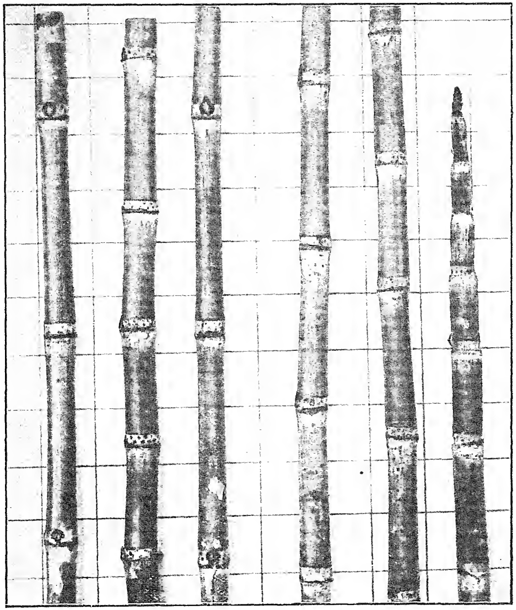
DHAULU OF GURDASPUR, TERERU.



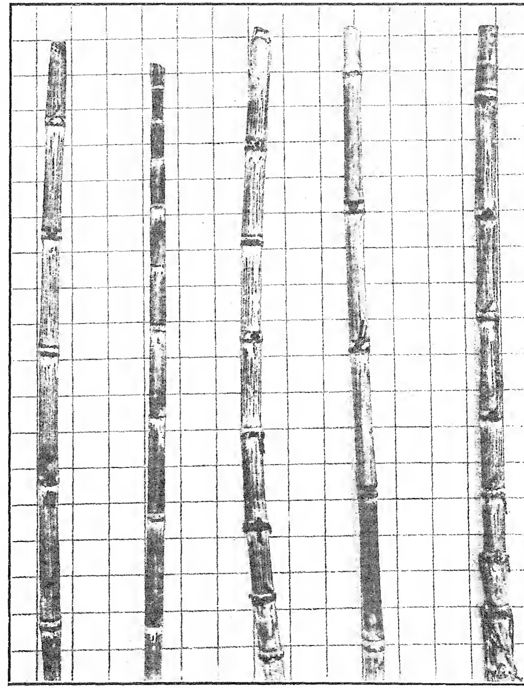
DHAULU GURDASPUR. 6 MONTHS OLD.
The black mark on the bamboo is just under 6 feet.



DHAULU GURDASPUR.



DHAULU OF GURDASPUR.



TERERU. GURDASPUR.
(on smaller scale)

DHAULU OF PHILLAUR.

1. General remarks on the distribution and classification of this cane.

A. Found in submontane tracts of Jullunder, Ludhiana and Ambala districts, also to a less extent in Hoshiarpur and the north of Karnal. From the agricultural point of view this variety is very like *Dhaulu of Gurdaspur*, in the general habit of growth, time of ripening and outturn and quality of *gur*. On close examination it is found to have a very broad root zone and no pronounced growth ring, differing in both these respects from *Dhaulu of Gurdaspur* and *Tereru*. The buds thus seldom reach the growth ring. The joints are also much bulged on the side opposite to the bud, thereby giving the cane a somewhat different appearance when cut.

(I am indebted to Mr. Southern for the above information.)

B. As stated in the Introduction, I have not met with this cane in the field. Shortly after my last visit to Gurdaspur in January 1914, Mr. Southern, touring in the Ludhiana and Jullunder districts and fresh from the study of the varieties collected at Gurdaspur in which he took much interest, wrote to say that he was convinced that the *Dhaulu* met with in these two districts was distinct from that in Gurdaspur. Specimens were accordingly sent down to Coimbatore where they were at once seen to be an additional member of the Punjab canes, differing in several important respects from the *Dhaulu* already examined from Gurdaspur. The canes sent down form the basis of the present description. They were not however entirely new to me for the following reasons:—

(1) Some specimens of *Dhaulu* obtained from Jullunder in September 1913 were noted as differing in several important respects from the local *Dhaulu of Gurdaspur* and threw at the time doubt on the fixity of the characters observed in that cane.

(2) In examining *Kanara of Jullunder*, grown for some years on the Gurdaspur Farm, in January 1914, certain canes were seen in the sample of a glaucous green in place of the bright green of the *Kanara* and, on further examination, proved to be a quite different cane.

(3) The *Dhaur* element of *Dhaur-Kinar*, from Meerut separated out by the farm staff at Gurdaspur, was examined and measured because I had failed to obtain good examples of this mixture at Aligarh. This variety was drawn and measured, and proves to belong to the same series.

(4) A cane of a similar nature called *Bodi*, growing at Gurdaspur and received some years ago from Aligarh, was gone through as if it was a Punjab variety, there being some doubts as to whether it had not crept into the more eastern districts.

All four of these are practically indistinguishable from the *Dhaulu of Phillaur*, excepting by some slight differences in thickness and other minor points. It was therefore without difficulty that the diagnosis was made at Coimbatore from the canes sent down. *Dhaulu of Phillaur* is a cane of the *Mango* class, and this is of special interest in that I had concluded that this eastern section of the North Indian canes was not represented in the Punjab. But it differs in some points from the typical members of the section. The canes are longer and thinner and grow to a greater height in the field than is usual. The *Mango* class appears to undergo this change in its migration towards the north-west and *Dhaulu of Phillaur* may be taken as representing the extreme limit of this elongation, and in fact may be, for the time, considered as a connecting link between the primitive *Dhaulu of Gurdaspur* and the short thick canes of the *Mango* class of the United Provinces and Bihar.

2. Specimens examined.

The canes forming the basis of the following descriptions and measurements were received at Coimbatore during the 1914

cropping season. No opportunity has been afforded of studying the foliage characters. The specimens have apparently come from the neighbourhood of Phillaur.

3. General characters of the variety.

Canes thin, practically straight-sided but slightly zigzag in lateral view, without prominent nodes, and leaf scars descending. Colour glaucous green to yellow below, yellow in lower parts of joints. Ivory markings present in all parts but lower joints often free; usually as a few long dark lines in the middle of the joint, passing through bloom band or not; sometimes anastomosing to a dense net-work. Scar line definite, dark brown. Growth ring practically non-existent as a separate layer, this character distinguishing *Dhaulu of Phillaur* from all other Punjab canes. Root zone broad, with ill-arranged widely separated root eyes. Circlet of hairs present, the hairs short and numerous. It however soon disappears upwards, especially under the bud, although traces are met with at other places most of the way up the stem. Buds small, rounded, sometimes blackening at base, bursting apically as a rule not nearly reaching the region of growth ring—another characteristic feature. Hairs not well developed; minute black hairs present. A few spines on the back of the leaf sheath in the specimens received, and the ligules rather large, arched above and with a fringe of fine silky hairs.

4. Cane measurements.

Total length of cane, average of 18 canes, 59·5″ with 22·7 joints.

Total length divided by average thickness at middle, $l. \div t.$ 97.

Length of joints in different parts of the cane, in inches:—1·6, 2·3, 2·8, 3·7, 4·3, 4·5, 4·6, 4·7, 4·6, 4·3, 3·9, 3·5, 3·2, 2·9, 2·2, 1·7, 1·4, 1·0, 0·8, 0·5, 0·3, 0·2, 0·1.

There are an unusually large number of terminal joints under 2″ in length, a characteristic feature of the *Mango* group.

Thickness of the cane at various points.

(*b*) Base 0·59″, middle 0·60″, top mature 0·59″. These figures show an average cane of surprisingly uniform thickness all the way up.

6. Colour of cane.

Glaucous green to yellow below; lower parts of the joints yellower. *Bloom band* visible, chiefly on younger parts, not well defined below these; descending distinctly but not thickly over the joint, giving a glaucous green above and whitish yellow below; hardly, thinly covering the growth ring and root zone.

Growth ring often scarcely a defined ring, but sometimes seen as a narrow and darker band above the root zone. *Root zone* usually yellower than the rest. Practically no *blackening* (slight in places but thinly diffused); *blushing* not apparent in the specimens.

Scar line rather distinct below the scarious edge of the leaf-scar, dark brown, sometimes interrupted immediately below the bud.

Ivory markings present in all parts, but the lower joints more often free; usually of a few long dark lines in the middle of the cane and here passing through the bloom band or not; in the upper joints a series of dark, parallel, sometimes anastomosing lines, in the upper two-thirds of the joints and passing through the bloom band. This form is very pronounced in *Bodi* where abundant splits occur. In *Dhaulu of Phillaur*, *splits* are also present but not so pronounced and arise from the ivory markings. *Groove marks* practically absent but the harsh black incrustation indicated here and there.

6. Characters of the joint.

Thickness, ovalness.—The thickness probably varies a good deal in different fields, some of the lots of canes sent down being thicker than others. The following are the averages of 15 canes, medial + lateral:—

Base 0·59″ + 0·64″, middle 0·60″ + 0·63″, top mature 0·59″ + 0·63″. There appear to be little traces of *ovalness* in any part, the cane being remarkably cylindrical.

Length of mature joints.—Average length in 18 canes 3·6″, average longest 5·6″, and average basal (shortest) 1·6″.

Shape viewed medially.—Practically straight-sided, without prominent nodes ; thickest at the leaf scar or region of the growth ring ; root zone narrowing downwards, hence the whole joint possibly slightly narrowing upwards ; younger, upper, immature joints distinctly bulged, especially in their lower third.

Shape viewed laterally.—Slightly zigzag with slight but distinct swelling below behind, the root zone taking part in the general downward curve ; hence the whole joint long concavo-convex, the upper immature joints are more plano-convex, the thickening being behind.

Leaf-scar slightly but distinctly *descending*, especially in the upper joints ; in the lower joints the scars tend to an alternately horizontal and descending position, as in many of the *Mango* group. Sometimes a distinct remnant of the leaf-scar forms a scarious *lip* under the bud. The *ending* is not decurrent.

Circlet of hairs present, short and numerous. Soon disappearing under the bud upwards on the cane, but some remains usually found right up the stem elsewhere, sometimes felt-like.

Groove absent.

Root zone, moderately wide, with moderately distinct eyes, widely separated and not forming definite rings, the lowest eyes often at some distance from the leaf-scar ; two to three rows.

Growth ring rarely traceable as a distinct band ; often practically absent, although the root zone has an upper boundary.

7. Bud.

Occasionally swelling below but hardly *shooting ; bursting* more or less apically, but sometimes tending to a slightly dorsal opening.

Small, rounded, sometimes blackened above ; not nearly reaching the growth ring except in young, upper joints.

Rising from the leaf-scar with occasionally a small, but distinct *cushion*.

Flanges, usually narrow borders round the upper part of the bud, rising high up, and often dark coloured; in younger joints sometimes rising lower down; never very prominent.

Bristles meagre, confined to a few strongish hairs round the apex; *basal patches* usually absent, but occasionally indicated or even present; *minute black hairs* present.

8. Leaf-sheath.

From the few sheaths attached to the canes sent down there appear to be a few *spines* on the back. The *ligule* is rather large and projecting upwards, rounded or angled broadly, with a fringe of longish silky hairs. These characters will need checking.

DESCRIPTION OF PLATE.

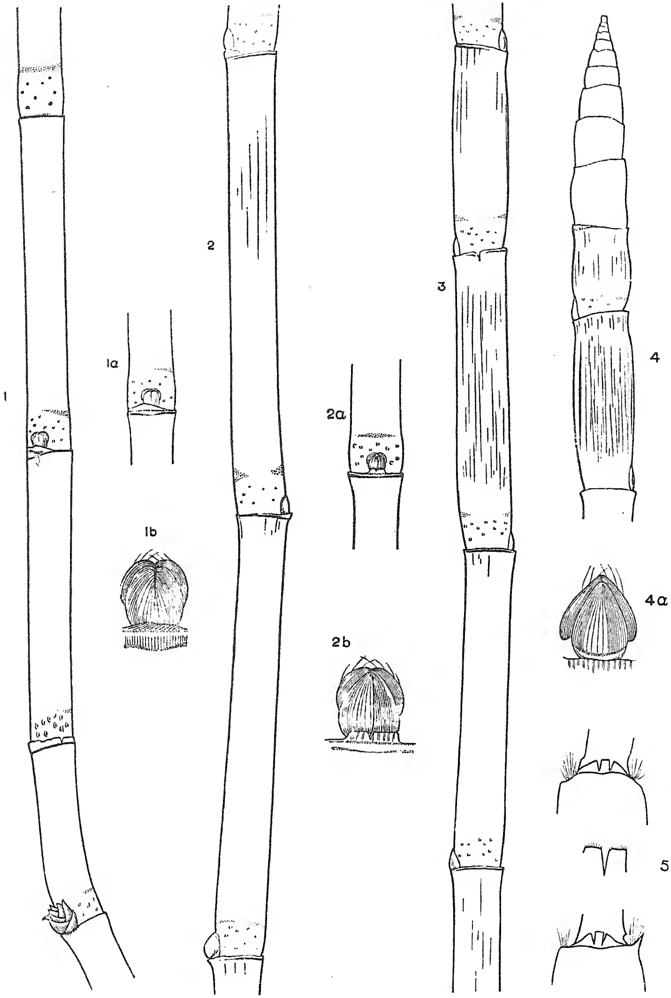
Dhaulu of Phillaur.

1, 2, 3, 4. Drawings made from one selected cane, the base, middle, and upper portions shown, as well as the end of the shoot. The buds are small and rounded, becoming elongated only near the tip (4*a*). Bursting is rather dorsal in the lower joints but soon becomes apical. The root zone is very wide but the eyes are rather irregularly disposed. The growth ring is practically absent, being occasionally indicated by a change in colour. The circlet of hairs is present only in the lower joints (1*b*) and soon disappears, and a sharply defined scar line is present. In the present case the scar line is interrupted under the bud but this is not usually so. The ivory markings are not common in the lower joints but increase in numbers upwards and there often pass through the bloom band and sometimes develop into splits. The leaf-scars are not accurately horizontal but are distinctly descending in places, especially in the upper joints.

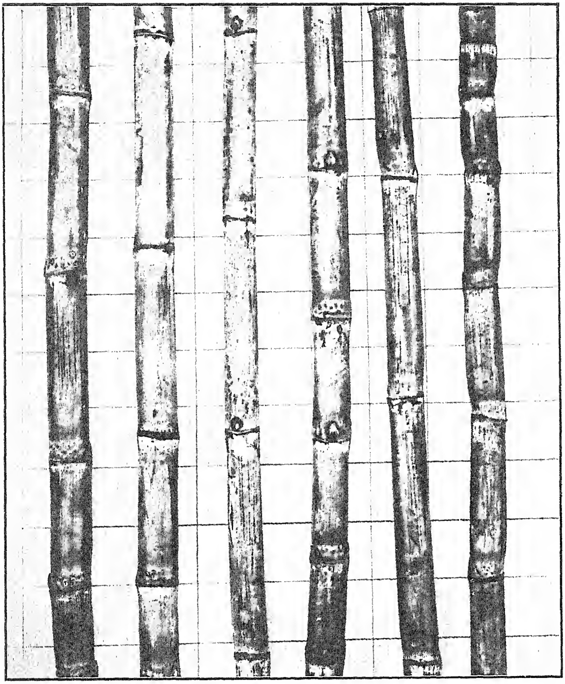
1*a*, 1*b*, 2*a*, 2*b*, 4*a*. Buds from various parts enlarged. The bud is not hairy; a few bristles are seen, but basal patches are usually

absent; minute black hairs are present (base of 4*a*). The flanges arise high up and are frequently dark coloured, forming a sharply marked border round the upper part of the bud. In 4*a* the bud is elongated, as is usually the case so high up the stem, the flanges arise below the middle and there is a trace of cushion under the bud.

5. A couple of junctions of lamina and sheath. The specimens were dried up when they arrived but appear to show a small ligular process and a rather high, arched ligule. The hairs on the edge of the latter are longer than in the *Katha* group.



DHAULU OF PHILLAUR.



DHAULU OF PHILLAUR.

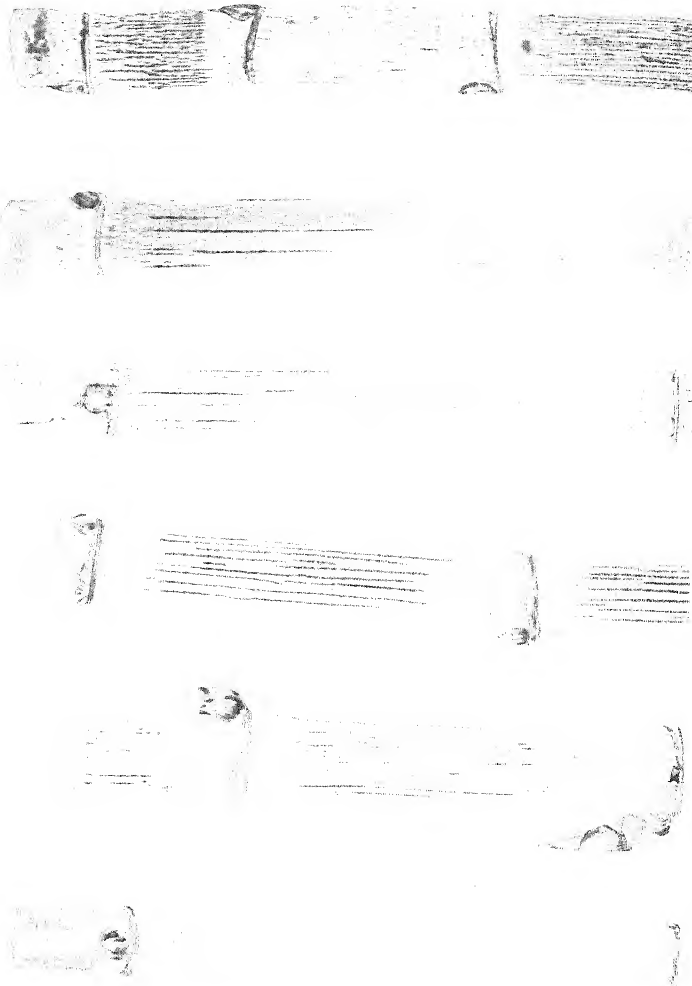
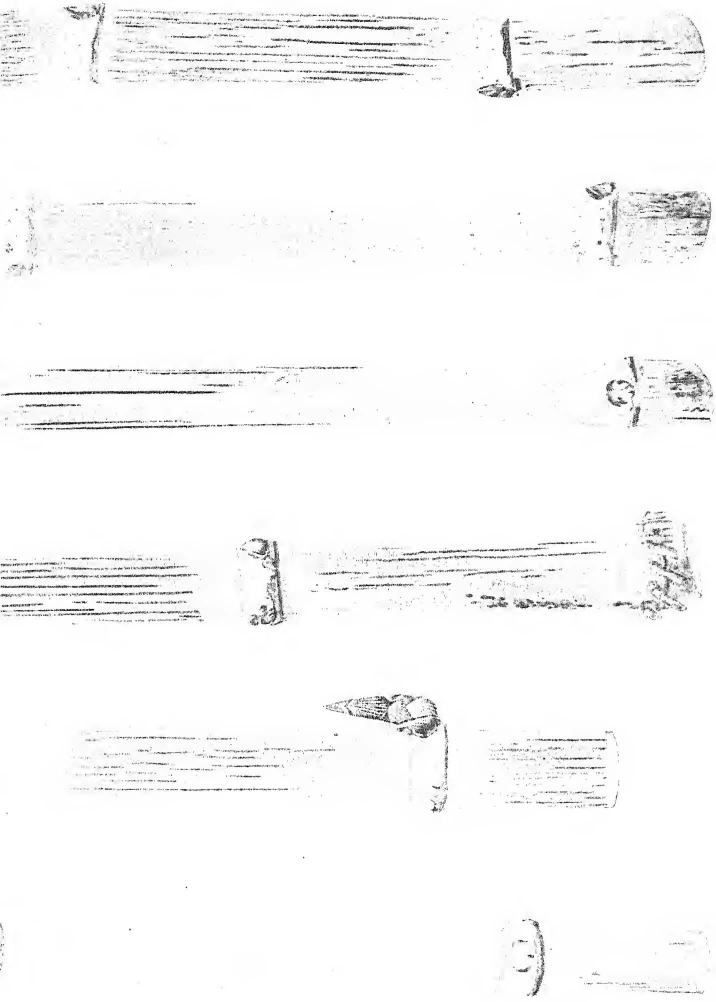


PLATE XIV.



DHAULU OF PHILLAUR

TERERU

DHAULU OF GURDASPUR

KAHU.

1. General remarks on distribution and agricultural and chemical characters.

A. *Kahu* is to be found widely distributed over the Province as a chewing cane near towns. As a gur-making cane it is practically confined to the Gurdaspur district, where the conditions for its growth are specially suitable. It is a green cane becoming paler on ripening, with broad leaves and a tall growing habit. It is the thickest cane in the Province from which *gur* is made. It requires more water, better land and cultivation than any of the other varieties and is subject to red rot. It ripens very late, yields very heavily and gives *gur* and *shakkar* of very superior quality. It has a soft rind which accounts for its being a favourite for chewing purposes.

(*Kahu* differs in many respects from all the other Punjab canes. It is the only *ganna* cane and, as these are frequently wiped out by disease, its susceptibility to red rot is explained. I have no information as to the migrations of this cane, but its allies are *Dikchan*, *Pansahi*, *Lata*, *Maneria*, *Chynia* and *Yuba*.—C. A. B.)

B. A soft, thick, juicy cane, yielding a poor quality of *gur* in frosty seasons; it is planted mainly on canal irrigated land but is beginning to extend to *chahi* and *saitab* lands as well. The variety was classified as " quickly affected by frost but quickly recovering " in the season 1912-3, but this year has been " non-resistant."

The average composition of the juice (average of the last three years) is :—

Month.	Sucrose %	Invert sugar %
November	10·75	4·14
December	12·47	2·37
January	13·34	2·00
February	14·45	1·61

It is fully ripe about the end of January. The *gur* made from various specimens of the variety yielded a sucrose content of from 69·84 per cent. to 74·14 per cent.

(For sections A and B I am indebted to Messrs. Southern and Barnes respectively.)

2. List of specimens examined.

Six months old.

(*a*) Gurdaspur, September 1913. Farm plot, irrigated; 12 canes examined, of which 6 were carefully measured as to joints and foliage characters. Canes and leaves drawn and habit of the field photographed.

Ten months old.

(*b*) Gurdaspur, January 1914. Farm plot, irrigated; 25 canes examined, of which 20 were measured as to thickness and length of joints. Canes drawn, painted and photographed to scale. Habit of the field photographed.

Twelve months old.

(*c*) Gurdaspur, March 1913. Bazaar canes (irrigated); 6 canes examined, drawn and photographed to scale.

(*d*) Gurdaspur, March 1913. Bazaar canes (rain-fed); 6 canes examined, drawn and photographed to scale. These canes appeared to be irregular and immature.

(*e*) Harchowal, March 1913. Cultivator's field; 6 canes examined and photographed to scale.

Most attention was paid to the first four of these sets of canes.

3. General characters of the variety.

Kahu is a moderate sized, upstanding variety with a heavy top of foliage. The canes are thick as compared with others of the Punjab and the rind is soft. The joints are arranged in a zigzag manner, with slightly decurrent leaf-scar end, bulged above the growth ring which is depressed, with swollen root zones and prominent nodes.

The canes are glaucous green to yellow, blushing purple where exposed between the leaf-sheaths. Ivory markings are absent. The circlet of hairs is reduced to a few long stiff hairs under the buds. The buds are large, ovate pointed, exceeding the growth ring, often arising some distance above the leaf-scar and provided with a distinct cushion. Bristles fairly developed but basal patches often meagre, minute black hairs present especially in the lower parts. Leaves broad and curving broadly back, closing into a rather dense tuft at the top. Sheaths not clasping the shoot widely and with characteristic purple blotches while living. Ligular processes absent.

4. Cane measurements.

Dead leaves at six months old. 7 to 14, averaging 10.

Length of cane and of shoot after stripping these. Cane 2′ 4″, shoot 6′ 4″, suggesting late development.

Total length of cane and number of joints at six and ten months,

(*a*) 47·2″ with 18·2 joints.

(*b*) 57·3″ with 21·5 joints.

These figures show a marked difference from those of other Punjab canes and appear to strengthen the idea of late development. A good deal of growth apparently takes place after September.

Total length divided by average thickness at the middle, $l \div t$:—

(*a*) six months canes, 56. (*b*) ten months canes, 74, indicating that the September canes had not reached their mature form.

Length of joints in different parts of the cane, in inches :—

(*a*) Average of 6 canes, 1·9, 2·7, 3·1, 3·2, 3·2, 3·3, 3·3, 3·4, 3·5, 3·4, 3·2, 3·3, 3·2, 2·3, 1·7, 0·8, 0·4, 0·1.

(*b*) Average of 20 canes, 2·7, 3·3, 3·8, 4·2, 4·2, 4·1, 4·0, 3·8, 3·6, 3·6, 3·3, 2·9, 2·7, 2·3, 2·0, 1·6, 1·3, 0·9, 0·5, 0·3, 0·1.

On comparing these two series of figures we note, as we did in *Katha* and others, that they differ in two respects. In the first place, the older canes have a larger number of short joints at their ends,

the minimum 0·1″ joint being much more gradually reached than in the six months canes. This we have put down to cessation of the growth in length at the end of the growing period. The older canes, in the second place, have, on the whole, longer joints at the base and sooner reach their maximum.

Thickness of the cane at various points.—The canes in *Kahu* are remarkably uniform in thickness in different parts. Occasionally they commence with half a dozen shorter joints, and these are narrow below and thicken upwards. Generally, there is a slight narrowing upwards in the upper half of the cane. The measurements of the 20 ten-months-canes were as follow :—

Base 0·75″, middle 0·75″, mature top 0·72″.

5. Colour of cane.

The cane in *Kahu* is of a glaucous green or yellow colour, the skin being light green or yellow under the bloom. The joints are yellower at the base. The youngest ones in the terminal shoot are apple green before the bloom appears in any quantity. The *bloom band* is moderately distinct as a band descending over the joint, even the growth ring occasionally having scales of wax on it.

The *growth ring* is green to brownish yellow according to age, but it is not a very marked layer. The *root zone* is cream coloured to stone yellow and ultimately brownish yellow, sometimes heavily bloomed.

Blackening is frequent, especially at the top of the joints where the bloom is greatest, these two being inter-dependent. *Blushing* of the joints is a constant character, those exposed to the light between the leaf-sheaths assuming a dark purple due to a brown skin under the bloom.

There is a *scar line* rather than a *scar band* above the bloom layer, but it is light in colour and not very pronounced. *Ivory markings* are apparently absent, as well as *splits*. The *groove* appears to be without marks of any significance.

6. Characters of the Joint.

Thickness, ovalness.—Average thickness in the specimens examined, lateral + medial:—

(*a*) 12 canes 0·36″ to 0·88″, averaging 0·84″.

(*b*) 20 canes base 0·75″ + 0·75″, middle 0·75″ + 0·78″, top 0·72″ + 0·76″. Average thickness at the middle, 0·77″.

(*c*) 6 canes, thickest 0·81″ + 0·83″, thinnest 0·64″ + 0·72″.

(*d*) 6 canes, thickest 0·81″ + 0·78″, thinnest 0·52″ + 0·50″ (immature).

(*e*) 6 canes, thickest 0·82″ + 0·84″, thinnest 0·67″ + 0·69″.

These thicknesses show remarkable uniformity, allowing for the canes in (*d*) being unripe. There is also extremely little ovalness.

Length of mature joints.

(*a*) average mature joint 3·2″, average longest 4·6″, average shortest 1·0″.

(*b*) average mature joint 4·7″, average longest 6·0″, average shortest 1·0″.

Shape viewed medially.—The joints of *Kahu*, viewed medially, are more or less straight-sided in the middle, but, owing to the prominent nodes, assume a general biconcave aspect, especially in the shorter joints. There are, however, a number of characteristic local swellings common to many canes, which are somewhat pronounced in most *Kahu* stems. The following may be taken as a typical, well developed joint :—the leaf-scar is the thickest part ; above it a more or less protruding root zone narrows upwards in a symmetrical curve on either side ; the growth ring is usually thinner, perhaps the thinnest part of the joint ; immediately above it a slight symmetrical swelling of the lower part of the joint causes the growth ring to lie in a depression exactly as if a string had been tightly tied round the joint at this place ; the joint then narrows upwards with curved surfaces to just below the bloom band, which is again one of the thinnest parts of the joint ; from this point the joint thickens out broadly and symmetrically through the bloom band upwards to the leaf-scar.

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The *growth ring* is green to brownish yellow according to age, but it is not a very marked layer. The *root zone* is cream coloured to stone yellow and ultimately brownish yellow, sometimes heavily bloomed.

Blackening is frequent, especially at the top of the joints where the bloom is greatest, these two being inter-dependent. *Blushing* of the joints is a constant character, those exposed to the light between the leaf-sheaths assuming a dark purple due to a brown skin under the bloom.

There is a *scar line* rather than a *scar band* above the bloom layer, but it is light in colour and not very pronounced. *Ivory markings* are apparently absent, as well as *splits*. The *groove* appears to be without marks of any significance.

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As these local thickenings occur in various degrees in other canes, it may be found convenient to include them in one comprehensive term. Unfortunately there is no such term known to me in comparative morphology but, ignoring the root zone, we may perhaps describe the joint as "ovate campanulate." This portion has the form of an ornamental urn and the root zone has the appearance of a suitable pedestal for it to rest on.

The root zone is not swollen in the immature canes (*d*) and in these even narrows downwards. In the short joints at the base of the cane, the shape is so far altered that the joints are narrow below and thicken broadly upwards.

Shape viewed laterally.—The joints are markedly zigzag; the general shape is concavo-convex, with a distinct swelling below behind above the root zone. Where this swelling is not present the joints are biconcave, for instance in the young upper joints of the canes. The typical joint has its anterior surface concave and its posterior distinctly sigmoid.

Leaf-scars often slightly descending, with or without a short strong lip. The outer *end* of the leaf-scar is often dark and sharply marked and is sometimes distinctly decurrent.

Circlet of hairs not well developed in *Kahu*, being restricted to a few strong straight hairs under the bud below and soon disappearing upwards. There are usually no hairs at other parts of the circumference.

Groove fairly well marked in thicker canes, often not distinct in thinner ones.

Root zone bloomed, usually tubercled below, swelling bell-like downwards, sometimes flat or even narrowing downwards, but this is usually due to the joints being young and immature or poorly grown. There are two rows of large eyes or one large one below and smaller ones above. Ivory markings have not been noted in the root zone.

Growth ring not usually a very marked or wide ring; often narrow and inconspicuous and generally depressed. The lower

margin is usually well defined but the upper is often rather difficult to make out, except by the cessation of bloom and the consequent changes in colour. Waxy flakes of bloom have been noted in some parts of the cane on the growth ring.

7. Bud.

These were not infrequently *shooting* in the specimens examined, usually *bursting* at the apex. They are large, elongated, ovate, pointed, extending beyond the growth ring; they often rise above the leaf-scar and have in consequence a more or less developed *cushion*.

The *flanges* are regularly present, rather narrow and extending beyond the apex.

Bristles moderately developed, sometimes white and confined to the inner part of the flange; *basal patches* present or not, meagre, their place being sometimes taken by minute black hairs. *Minute black hairs* present, chiefly near the basal patches and sometimes taking their place.

8. Leafy shoot.

Leaves moderately widely spaced on the stem but closing in at the upper end to a congested tuft, this being especially noticeable in the older canes where all the younger leaves are dead. Usually about 7 visible leaves in the *terminal tuft*, placed in the last two inches of the shoot.

Number of terminal joints under 2″ long, 4 in the six months canes, 6 in the ten months.

(*a*) six months old 2·3″, 1·7″, 0·8″, 0·4″, 0·1″.

(*b*) ten months old 2·0″, 1·6″, 1·3″, 0·9″, 0·5″, 0·3″, 0·1″, showing the slower apical growth in the maturing canes.

9. Leaf-sheath.

Length of the sheaths in the young, vigorous, six months old plants; average of six canes, in inches :—8·0, 9·0, 9·1, 8·9, 8·9, 9·1,

9·4, 9·3, 9·4, 9·3, 9·3, 9·6, 9·5, 9·1, 9·2, 9·1, 8·8 (8·2, 5·5, 1·0, 0·3, 0·1). *Average longest* in the six canes 10·3″.

The colour of the dead leaf-sheaths is perhaps slightly pink, but a good deal obscured by blotches of brown. The living sheaths are characteristically marked by dark purple stains, this colouration being seen in all the members of the class. They are rather heavily bloomed. The *scarious border* arises late and is apparently a result of the death of the edge of the lamina above it.

There are no *silicious spines*, but the surface is rough behind. The minute *hairs* between the veins behind are distinct under the lens and black coloured below. The base of the sheath does not *clasp* the stem widely.

Proportional width of sheath to lamina at junction :—20 : 24, 18 : 22, 20 : 23. As a natural consequence of these small differences, the *ligular processes* are absent. *Ligule* very narrow, with a lozenge in the middle, hardly clothed on the edge with minute hairs, which soon disappear.

10. LAMINA.

Width considerable, about 2″ on the average, the maximum width varying from 1·8″ to 2·2″ in the six canes examined.

Length. Average lengths of lamina in six canes, 2′ 0″, 2′ 6″, 2′ 11″, 3′ 0″, 3′ 2″, 3′ 2″, 3′ 3″, 3′ 5″, 3′ 5″, 3′ 6″, 3′ 9″, 3′ 11″, 3′ 10″, 3′ 10″, 4′ 0″, 4′ 0″, 4′ 0″. Average longest 4′ 2″.

These are the visible leaves. It is quite probable that greater lengths might have been reached later in the season.

Proportion of length to width, 23 to 1, very different figures from those usual in the Punjab canes.

Not *channelled ;* slightly, loosely embracing the shoot at the base, the edges sinuate at the base. *Transverse* marks dull or brownish green, varying. *Serrature* at middle harsh persistent, of short, sharp, close-set, rather straight, low-lying spines.

Proportional width of mid-rib to lamina, at base, 0·20 : 1·50, at 1″, 0·20 : 1·53, at 6″, 0·20 : 1·56, at 12″, 0·19 : 1·75.

DESCRIPTION OF PLATE.

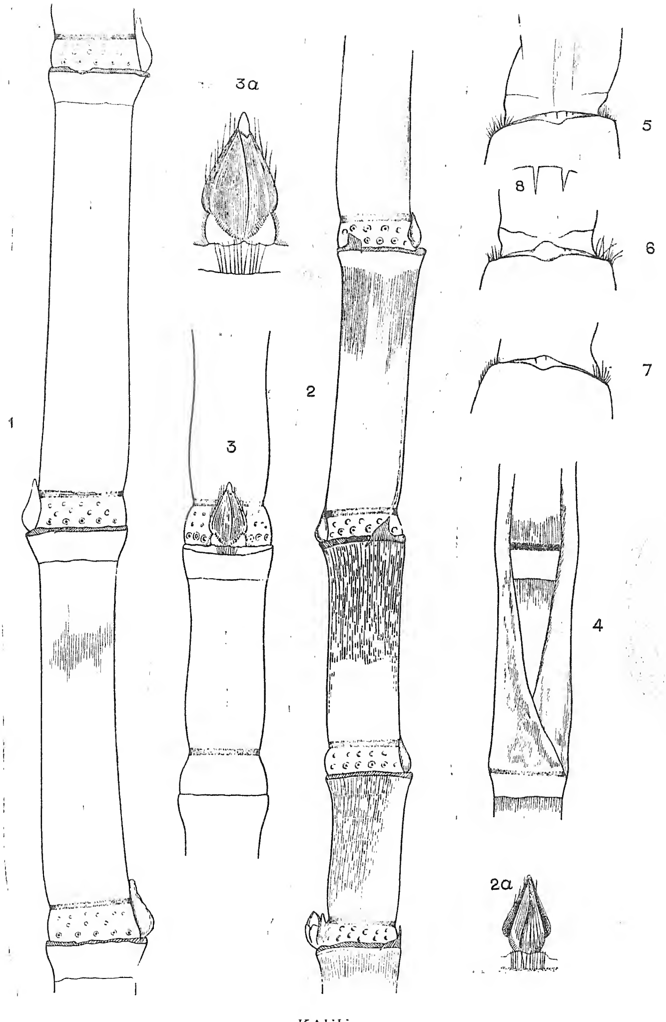
Kahu.

1. Joints of a six months cane. These are concavo-convex, with a swelling below behind. They are zigzag but the leaf-scar is practically horizontal. The root zone is swollen, increasing in thickness downwards. The growth ring is narrow and depressed. The bud is large and bulged below; its tip projects beyond the growth ring. There is a distinct, blunt shelf or ledge under the bud forming a truncate lip. The circlet of hairs is not in evidence.

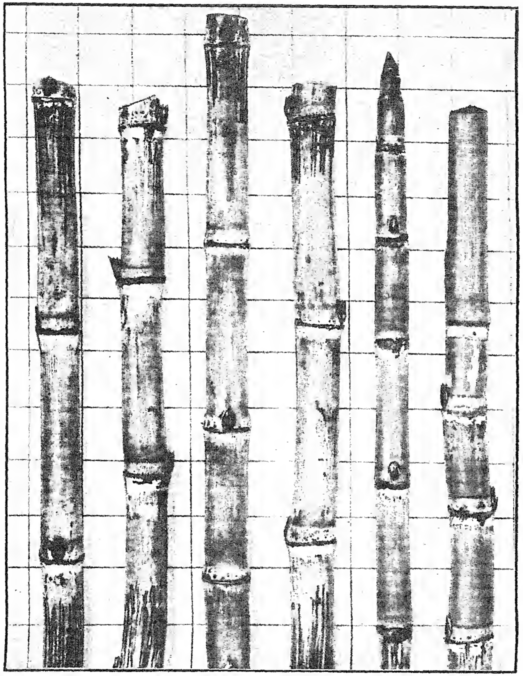
2. The lower part of a ten months cane. It is blackened below, especially in the upper part of the joint. The characters noted above are maintained. The leaf-scar ending is distinctly decurrent for a short distance, as seen in the two upper nodes. 2a is the enlarged bud of the top joint.

3, 3a. Medial view of a couple of joints of a ten months cane. The characteristic shape of the joint is seen from leaf-scar to leaf-scar; this has been called ovate campanulate above the root zone and the latter thickens bell-like downwards. The remnant of the circlet of hairs is seen as a few strong bristles under the bud. There is a well-marked cushion, the bud rising at a little distance above the leaf-scar. The bud bursts apically and is ovately elongated or even triangular. The flanges arise low down and form a narrow border to the upper part of the bud. Hairs are not very pronounced but bristles and basal patches are present.

4. The upper part of a ten months cane showing the leaf-sheath clasping the stem narrowly. The base of the lamina is not very much narrower than the leaf-sheath and there are no ligular processes. The ligule is narrow but has a lozenge-shaped expansion in the middle. The hairs on its edge (8) are meagre and quickly disappear.



KAHU.



KAHU, GURDASPUR.
(The streaks at the ends are not ivory markings but scratches in the surface.)

KAHU, GURDASPUR, 6 MONTHS OLD.
(The white mark on the bamboo is just under 6 feet.)

KANARA OF JULLUNDER.

1. General remarks on distribution and agricultural and chemical characters.

A. *Kanara* is very little grown in the Punjab, although it is often seen in small quantities in the submontane tracts to the east of the Beas. It is an unimportant cane from the agricultural point of view.

It is slightly thicker than *Dhaulu of Gurdaspur* and ripens to a bright green colour. It is very seldom grown pure, has a soft rind and is mostly used for chewing. Owing to its soft rind it is very liable to be wiped out by frost, which happens periodically in severe winters. (*Kanara* is interesting from the morphological point of view and appears to me to present several primitive characters. In the Introduction I have stated the case for its periodic introduction from the neighbourhood of Meerut, but its very narrow leaves and the persistence of the circlet of hairs bring it near to the primitive *Katha* canes and it is possible that it, like *Katha* and *Dhaulu*, may have been derived from *Saccharum spontaneum*. I look forward to tracing its relationships in other Provinces and may some day be able to suggest a line of development divergent from those given for *Katha* and *Dhaulu* to thicker canes further east.——C. A. B.).

B. A cane which, being harder than *Dhaulu* and softer than *Katha*, gives a juice of high specific gravity, but yields a less quantity under the iron *belna* than all of the other seven types under report. It is new to the District and was planted on the Farm in the season 1913-4, when about half of the plot gave *shakkar*. The variety may be classified as semi-frost-resistant on the results of this season's experiments.

The average composition of the juice in the season was :—

Month.	Sucrose %	Invert sugar %
November	11·81	4·19
December	13·47	2·76
January	14·19	2·40
February	16·17	1·22

It is fully ripe about the middle of February.

(For the details in sections A and B, I am indebted to Messrs. Southern and Barnes respectively).

2. List of specimens examined.

The specimens examined were from the farm plots at Gurdaspur for which the canes had been obtained from Jullunder.

Canes six months old.—(*a*) Gurdaspur, September 1913. Farm plot, irrigated; 12 canes examined, six of which were measured as to their joints, leaf-sheaths and laminas. Canes drawn and field photographed.

Canes ten months old.—(*b*) Gurdaspur, January 1914. Farm plot, irrigated; 25 canes examined of which 20 were measured as to their joints. Canes drawn, painted and photographed to scale and the field photographed.

3. General characters of the variety.

In minute points this cane seems to stand somewhat between *Katha* and *Dhaulu of Gurdaspur*. Canes moderately thin and often oval in section, grooved, straight, with shorter joints and more prominent nodes than in *Katha*, and therefore the joints biconcave, especially in medial view. Colour bright green, the bloom not descending much over the joint and thereby hiding the natural colour. Cut and stripped canes soon turn a bright red pink on exposure. The red brown marks in the groove seen in *Katha* are found in *Kanara*. There is either a scar line or a scar band. Ivory markings are not common but, when they occur, they frequently pass through the bloom band. Circlet of hairs present,

persistent all the way up, the hairs becoming shorter and fewer upwards. Buds short, small, squared, not reaching the growth ring, bursting dorsally; not well provided with hairs, but minute black hairs present. The leaves are very narrow, although somewhat wider than in *Katha;* the young leaves resemble those of *Dhaulu of Gurdaspur* in being erect, strict, without bent tips. The lamina is rather channelled at the base, the leaf-sheath does not embrace the stem widely and the ligular processes are small or absent.

4. Cane measurements.

Dead leaves at six months old, average 10.

Length of six months cane after stripping dead leaves.—The canes averaged 2′ 4″, the shoot 6′ 3″. These figures suggest slow initial growth in this variety.

Total length of cane and number of joints, at six and ten months :—

Six months canes (*a*) 49·6″ with 21·3 joints.

Ten months canes (*b*) 54·2″ with 25·5 joints.

Total length of stripped cane divided by average thickness at the middle, $l. \div t.$

(*a*) 82, (*b*) 85.

Length of joints in different parts of the cane, in inches :—

(*a*) 1·3, 1·9, 2·4, 2·7, 3·0, 3·0, 3·1, 2·9, 3·1, 3·0, 3·1, 3·0, 2·9, 2·6, 2·7, 2·6, 2·1, 2·1, 1·1, 0·3, 0·1.

(*b*) 1·1, 1·5, 2·0, 2·4, 2·8, 3·0, 3·2, 3·3, 3·3, 3·1, 3·0, 3·1, 3·1, 3·0, 2·9, 2·6, 2·2, 1·8, 1·6, 1·3, 0·9, 0·6, 0·4, 0·2, 0·1.

A comparison of these two sets of figures shows at once how rapidly the end of the shoot is growing at six months and how slowly at ten. It is also to be noted that the basal joints of the ten months canes are not any longer than those at six months, as is the case so markedly in *Kahu* and *Lalri.* The two series of measurements are so similar that we can readily believe that we are dealing with the same set of canes at different periods of growth, the measurements running parallel until we come to the terminal shortening

region. Turning to the full list of measurements of which these are the averages, we do however find the two classes of canes noted in *Kahu*. There is one cane with far fewer joints than the rest, and it has long basal joints, and there is also another with an average number of joints which shows a similar tendency. The figures for these two are given below and show that they are fairly comparable, but that one has an unusually large number of short terminal joints :—

No. 11. 2·7, 3·3, 3·6, 4·1, 4·1, 3·8, 3·5, 3·4, 4·3, 4·3, 4·4, 4·5, 2·2, 2·0, 1·9, 1·0, 0·5, 0·3, 0·1.

No. 6. 2·5, 3·1, 3·3, 3·4, 3·8, 3·5, 3·4, 3·1, 3·9, 4·1, 2·6, 2·2, 2·5, 2·2, 1·8, 1·9, 1·8, 1·2, 1·2, 1·0, 0·6, 0·5, 0·3, 0·2, 0·1.

But the great majority, 18 of the 20, have short basal joints, gradually increasing in length as in the typical six months canes. From this we are, I think, justified in gathering that the *Kanara* canes are rather late in developing, and there is little of the distinction between early formed and late formed canes which we note in certain other varieties.

Thickness of the cane at various points.—The canes are practically uniform, excepting that the lower joints are sometimes short and narrow, each joint thickening from base to top. Average thickness in (*b*), at base 0·60″, at middle 0·60″, at top 0·62″.

5. Colour of cane.

Canes green or yellowish green, being yellower in the lower parts of the joints. The youngest joints are of a clear apple green. The *bloom band* is moderately distinct, especially in the greener joints but descends comparatively little over the joint, thus readily distinguishing this cane from the usual glaucous green ones of the tract. This colour makes it easy at once to pick out the *Dhaulu* admixture in *kanara* plots. *Blackening* is not markedly present. The canes *blush* readily to a rather bright red pink after cutting. The *growth rings* are greenish to yellowish brown according to age and the *root zone*, similarly, greenish yellow to bone yellow. A *scar*

line is sometimes present of a light brown colour, but a *scar band* is also sometimes met with. *Ivory markings* are not very common and these often pass through the bloom band. In the youngest parts of the cane there is often a joint with many close parallel lines in the middle of the joint, as in so many other kinds of canes. The young parts are often *split* in the covered-up bud portion. The *groove* not infrequently shows the red brown marks which have been taken to be characteristic of the *Katha* alliance as contrasted with the *Dhaulu*.

6. Characters of the joint.

Thickness, ovalness.

(*a*) Average of six canes at the middle, lateral+medial 0·57″ +0·64″.

(*b*) Average of 20 canes, base 0·60″+0·60″, middle 0·62″+0·60″, mature top 0·61″+0·67″. These figures suggest an *oval cane* and this character is seen, the moment the canes are cut and stripped.

Length of Mature Joints.

(*a*) Average 2·66″, average shortest (basal) 1·3″, average longest 3·5″.

(*b*) Average 2·63″, average shortest (basal) 1·1″, average longest 3·8″.

Shape viewed medially.—Slightly biconcave, the growth ring being the thinnest place and the joints gradually thickening upwards; root zone slightly swollen and the leaf-scar the thickest part. Hence the joint is elongated campanulate above the root zone, and differs from *Kahu* chiefly in the less prominent nodes and the absence of the swelling above the growth ring.

Shape viewed laterally.—Slightly thickening upwards, biconcave or concavo-convex, according to the development of the slight thickening below behind. The relative thickness of parts in other respects is similar to that in the medial view.

Leaf-scar, practically horizontal but occasionally slightly descending, and without definite *lip*.

Circlet of hairs present and persistent most of the way up. Getting shorter and more meagre upwards.

Groove rather distinct, narrow, all the way up the joint. Sometimes with a rather deep depression above the bud and not infrequently with the brown red mark characteristic of *Katha* canes.

Root zone not wide, usually slightly swollen, bell-like, downwards; eyes hardly tubercled, in 2-3 moderately distinct rows.

Growth ring narrow, flat to slightly raised, but lower than root zone.

7. Bud.

Shooting not noted; *bursting* dorsally.

Short, small, squared, sometimes protruding hemispherically, not reaching growth ring.

Arising close to the leaf-scar which has often to be removed to note the characters of the small bud.

Flanges small and not very conspicuous, rising rather high up, narrow below but broad and often squared above the apex.

Bristles not pronounced; *basal patches* poorly developed or absent; *minute black hairs* present.

8. Leafy shoot.

Leaf end not apparently bent as in *Katha*.

Number of terminal joints under 2", 3 at 6 months and 8 at 10 months.

(*a*) 2·1, 1·1, 0·3, 0·1.

(*b*) 2·2, 1·8, 1·6, 1·3, 0·9, 0·6, 0·4, 0·2, 0·1.

These figures show, in a pronounced manner, the slowing down of apical growth towards the end of the season, and are perhaps characteristic of a shorter-jointed cane than *Katha* and *Dhaulu*.

9. Leaf-sheath.

Length.—Average length in six months canes, in inches:—

(*a*) 8·2, 8·8, 9·7, 9·9, 10·3, 10·6, 10·6, 10·8, 11·0, 11·0, 10·9, 11·1, 11·1, 11·3, 11·2, 11·3, 11·3, 11·2, 11·0, 11·1, (10·4, 9·0, 2·2, 0·3, 0·1, in bud).

Longest sheaths in the several canes 12·4″, 13·3″, 10·8″, 12·4″, 11·5″, 11·6″. *Average longest* 12·0″.

Not bloomed, with clear parallel veins, those recently dead not becoming clear crushed strawberry coloured.

Scarious border apparently forming rather early and before the death of the lamina edges; *edges* of the upper, younger leaf-sheaths frequently browned.

Hairs at junction of leaf-sheath and lamina descending along the edge of the sheath; hairs between the veins behind just visible under the lens, blackened below.

Base of the leaf-sheath not *clasping* the shoot widely, practically as in *Dhaulu*.

Proportion of base of lamina to top of leaf-sheath; rather varying in the specimens examined, 10:13·5, 11·5:13·5, 10·5:15·5. This last one, as might be expected has a small ligular process. These figures require checking in further specimens.

Ligular processes absent, indicated or small.

Ligule narrow, not indented below, with a fringe of smallish but distinct hairs.

10. Lamina.

Width, usually under 1″, but occasionally reaching that figure.

Length in the six shoots examined including all leaves with visible tips; averages from base upwards:—

2′ 2″, 2′ 3″, 2′ 4″, 2′ 10″, 2′ 8″, 3′ 2″, 3′ 2″, 3′ 2″, 3′ 5″, 3′ 5″, 3′ 6″, 3′ 2″, 3′ 2″, 3′ 7″, 3′ 7″, 3′ 8″, 3′ 8″, 3′ 8″, 3′ 9″, 3′ 8″, 3′ 8″, 3′ 8″, 3′ 2″, 2′ 7″, 1′ 10″.

Average longest in these six canes 3′ 10″.

Proportion of length to width, 46 to 1.

Rather *channelled* at the base, slightly, loosely embracing the stem.

Transverse marks dull blackish green, lightly bloomed.

Serrature harsh persistent, made up at middle of minute, scattered hairs.

Proportional width of mid-rib to lamina.

At 1″ from base, 0·20:0·50, at 6″, 0·16:0·55, at 12″, 0·14:0·75.

DESCRIPTION OF PLATE.

KANARA OF JULLUNDER.

1. Portion of a six months cane. The root zones are rather narrow but the buds are very small and do not reach the growth ring. The latter is distinct and narrow and not very deeply coloured. The circlet of hairs is well marked.

1a. Medial view of the middle node of 1, and 1b, the bud enlarged. The bud is circular with a flat top formed by the narrow flanges which arise about the middle. Bursting is markedly dorsal. The bud is sunk in a rather pronounced depression at the base of the groove. A comparison of 1 and 1a, shows that the cane is oval in section.

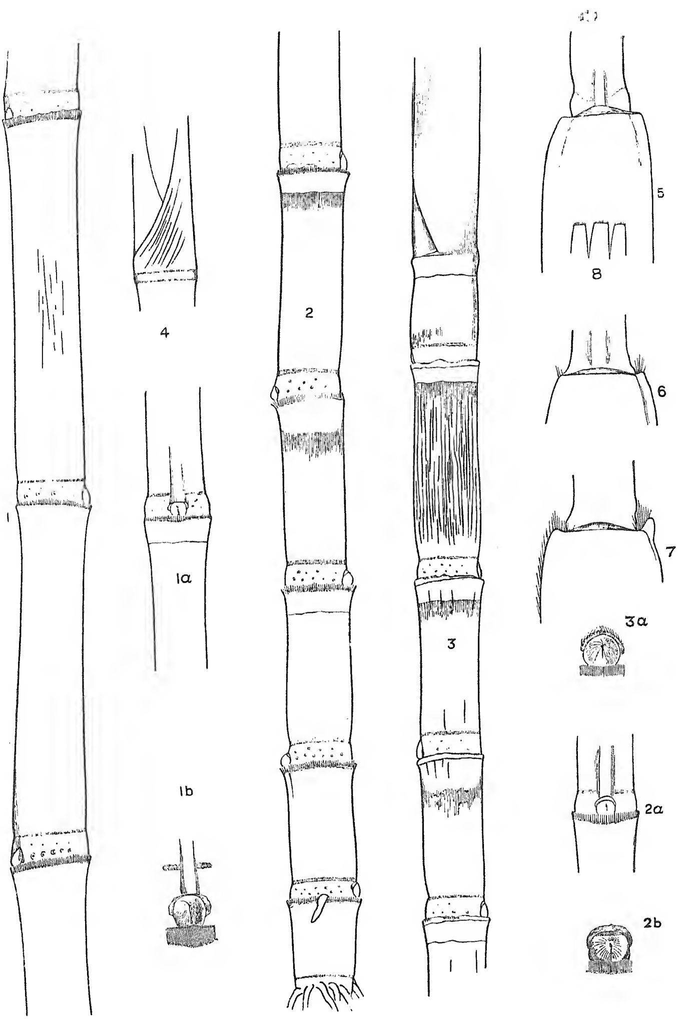
2, 3. The base and top of a ten months cane. The characters noted above are maintained. The root zone is narrow and rather swollen downwards. The buds are very small, rounded or flat-topped and bursting dorsally. The circlet of hairs, well developed and persistent most of the way up is only present here and there at the top. The ivory markings are sparse below and pass through the bloom band above. One joint has a mass of ivory markings, as in *Katha*, but these extend here almost the whole length of the joint, instead of being confined to one part, as in *Katha*.

2a, 2b, 3a, buds of 2 and 3. The vestiture of hairs is not very well developed, but varies.

4. The top of a six months cane, showing the leaf-sheath clasping the stem widely at the base.

5, 6, 7, 8. Junction of lamina and leaf-sheath. Ligular processes are small or absent and the tuft of hairs descends along the edge of the leaf-sheath in 7. The ligule appears to be rather narrow. The hairs on its edge (8) are minute.

COIMBATORE,
April, 1914.



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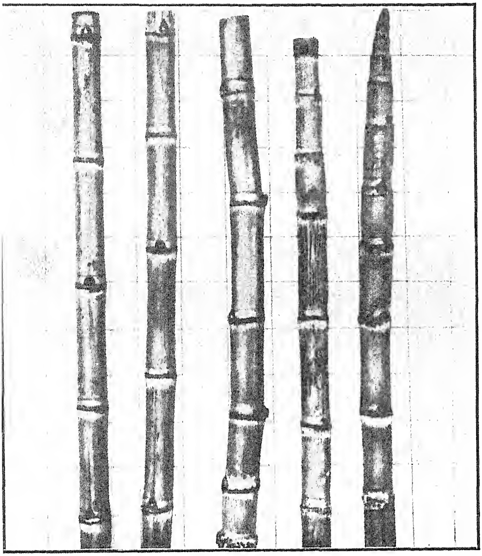

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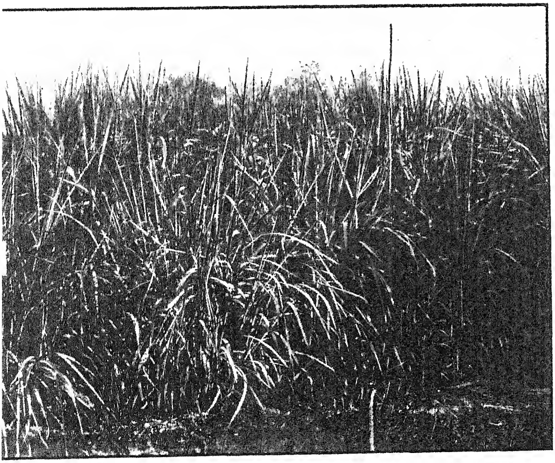


KANARA OF JULLUNDER, 6 MONTHS OLD.
(The black mark on the bamboo is just under 6 feet.)

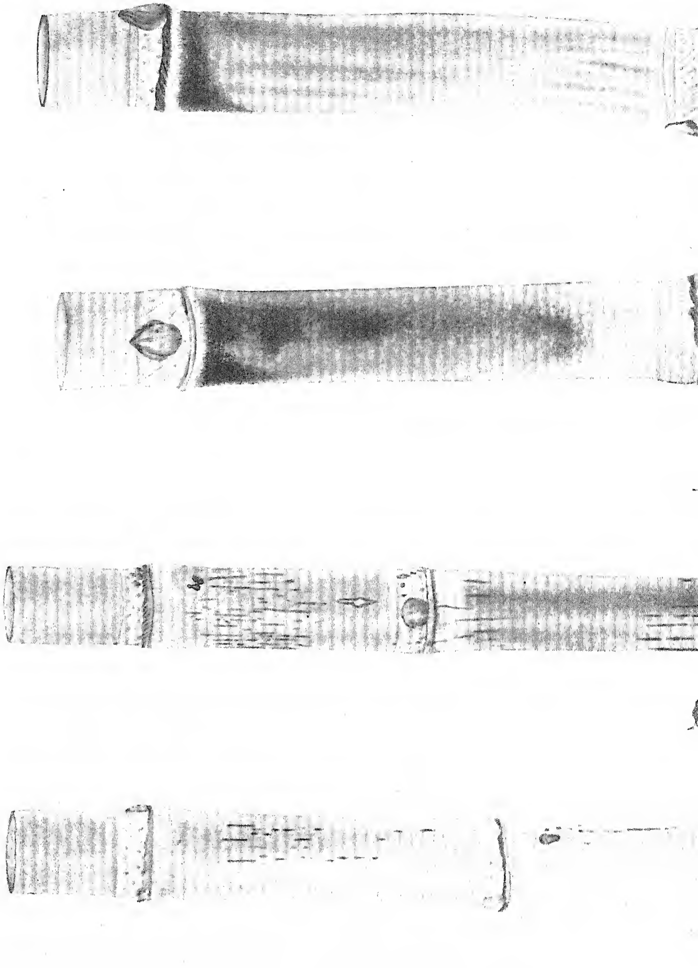
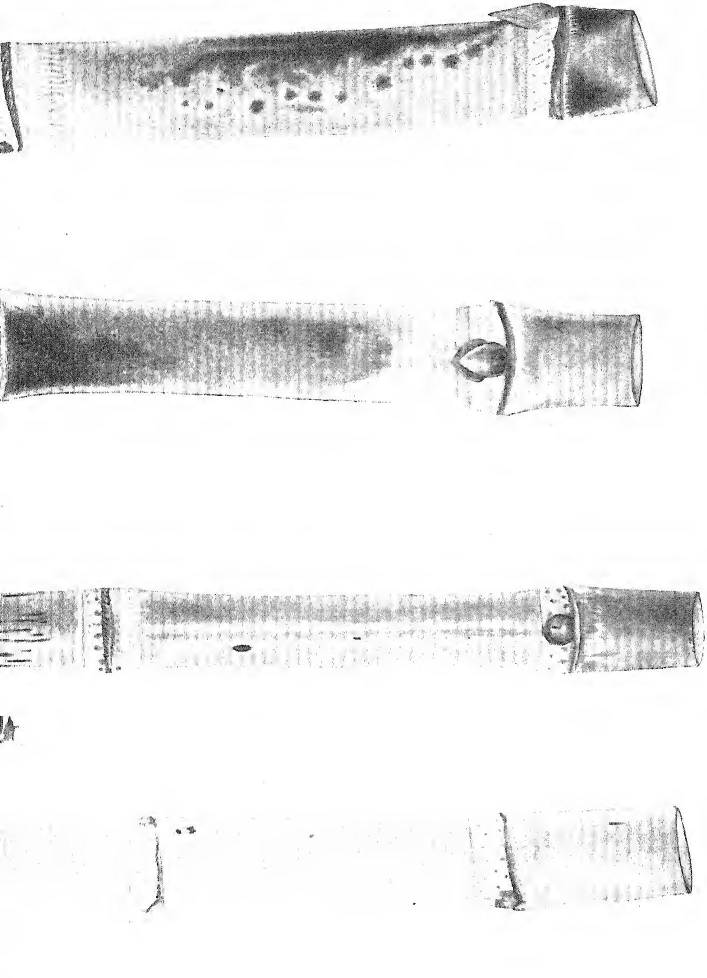


PLATE XIX.



KAHU

KANARA OF JULLUNDER

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THE DISTINGUISHING CHARACTERS OF SUGARCANES CULTIVATED AT SABOUR

BY

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AND

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Assistant Professor, Agricultural College, Sabour

WITH A NOTE ON THE CHEMICAL CHARACTERS

BY

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THE DISTINGUISHING CHARACTERS OF SUGAR-CANES CULTIVATED AT SABOUR.

BY

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I.—Introduction.

Origin of Work.—In the year 1908 it was decided that the sugarcane crop should be studied at Sabour both from the chemical and botanical standpoints. Arrangements were therefore made by Mr. C. Somers Taylor for the collection through the Divisional Agricultural Inspectors of the principal varieties of cane grown in Bengal. Thirty-three varieties (including two pairs of duplicates) were collected and planted on the Sabour farm in February and March 1909. The observations published in this paper were made on selections from these varieties and are not necessarily true of all local varieties with the same name to be found in various parts of the Province.

Method of Selection.—The original samples had been procured from the fields of cultivators and were presumably fair average

samples of the cane grown under that varietal name in the area in question. These were planted in February and March 1909, half the quantity being planted as whole canes and half as cuttings. At the end of the season mass selections of the best canes of each variety were made and the selected canes planted in March 1910. In some cases the canes of a variety were divided into two groups according to the relative size of the nodes and internodes or the colour of the canes, and these were sown in separate plots. No differences however were noted between the canes of the plots derived from these selections. By the beginning of the next season (February 1911) some idea had been obtained of what were the constant distinguishing characters of the cane varieties and it had become clear that some of the varieties did not consist of one uniform type. It was therefore decided to select two single bushes of each variety that appeared to be pure and two single bushes of each of the types that were suspected to be present in some of the other varieties. At the time of making these selections each bush was examined in detail both in the field and laboratory. Since 1911 these pure lines have been grown in pure culture and have provided the material on which all the observations recorded in this paper have been made.

By growing the cane in pure culture we were able to prove by means of the botanical evidence that certain of the varieties[1] were impure and at the same time our observations regarding all the types examined were placed on a firm foundation. Our observations were confirmed by those of Mr. Taylor[2] and the combined

[1] In this connection it may be mentioned that the cane which came from Behta under the name of *Ketari* was found to be a mixture of two components similar to two other types of tall canes, namely, *Bansa* and *Baraukha*, which types have been separated out and called *Ketari No. I* and *Ketari No. II* respectively. Another cane of the same name was received from Kanti in Muzafferpur. This cane agreed neither with *Bansa* nor with *Baraukha* but was similar to *Maneria*, hence this has been called *Ketari No. III*. Similarly the cane which came from Behta under the name of *Chynia* was found to be a mixture of *Baraukha* and *Maneria* types; these types have been separated and are described under *Chynia* No. I and *Chynia* No. II.

[2] This is well illustrated by the case of the fibre content of *Chynia* varieties quoted by Mr. C. S. Taylor in page 3 of his "Notes on Experiments with Sugarcane at Sabour." (*Bulletin No.* 39, *Agricultural Research Institute, Pusa*), and somewhat similar results were obtained in the case of *Ketari*.

observations show clearly that the value of any accurate work on the chemical or other characters of varieties is likely to be very largely discounted if the varieties have not been derived from single plant cultures.

PROGRESS OF WORK.—In the first two years of the experiment preliminary field observations were made with a view to finding out what were the distinguishing characters of the cane. In the spring of 1910 the following characters were under examination :—

I.—Field characters.

1. Number of stems on a stool.
2. Average height of canes in field.
3. General appearance of cane, uprightness or otherwise of plant in young or older stages.

II.—Leaf.

4. Appearance, such as straight, upright, bent over, etc.
5. Proportion of withered leaves to green ones.
6. Breadth of leaves at middle.
7. Leaf edge.
8. Length of leaves.
9. Colour of leaves.
10. Colour of leaf sheath.
11. Colour of band at base of leaf.
12. Presence of hairs at leaf base.

III.—Stripped canes.

13. General colour of cane.
14. Thickness of cane at internodes and nodes.
15. Length of internodes.
16. Colour above node.
17. Colour of internodes.
18. Presence of wax and colour of wax.
19. Appearance of buds—eyes well developed or not.
20. Appearance of canal above buds.
21. Have eyes sprouted !

In the following spring (1911) single plants were selected in the field and then taken to the laboratory, where careful measurements were made of the canes and leaves according to the same system as is used at present. These measurements, however, are not strictly comparable owing to the fact that in that year all the canes (whether mature or immature) of the selected stools had perforce to be examined in order to give a maximum of material, whereas since 1913 the observations have been confined to ten canes selected from a batch of 100 average mature canes selected from the whole plot. At the time of harvesting the 1910 crop a series of observations were made on the length, number of internodes and diameter of cane in all the varieties. In December 1911 special attention was paid to the study of the flowering of the cane. Owing to a misunderstanding single plant selections were again made from the 1911 crop in 1912, observations on the single plants being made on the same lines as in the previous year. This has somewhat complicated the records and has resulted in our present cultures being derived from single plants selected from single plants, a somewhat unnecessary refinement. In the spring of 1913 the 1912 crop was examined according to the present system and only the best cultures of each variety were reserved for planting. The observations made in 1913 were carefully checked on the mature plants of the 1913 crop in the spring of 1914.[1]

METHOD OF CULTIVATION.—The sugarcane varieties under examination have either been grown on the farm or in the Botanical area. Cane is usually grown here on land which has lain fallow or been under a leguminous crop during the previous rains. In November the land is ploughed and cross-ploughed to a depth of 6″ to 9″ with Rajah ploughs. Cowdung manure is then applied at the rate of 200 maunds per acre and is ploughed in with Rajah ploughs, after which the land is cultivated and laddered some four times or as often as is necessary to mix the manure, keep down weeds and conserve the moisture. In January arrangements are made for irrigation and the land is laid out in alternate trenches and ridges,

[1] *Vide* Appx. II.

each 3′ wide, the trenches being about 6″ below the level of the ridged land. Rape cake is then applied at the rate of 10 maunds per acre to the trenches and is forked into the soil which is then irrigated. After the trenches have dried sufficiently they are dug over with forked *kodalis* and are ready for planting which is usually carried out in February. The canes for planting are examined carefully for red rot as they are being cut into lengths, each length having 3 good buds; they then have their ends dipped in tar and are ready for planting. (When white-ants are likely to be particularly troublesome they are dipped in a decoction of *neem* leaves before tarring). The cuttings are then planted in 2 V-shaped furrows down the 2 outside edges of the trenches, the cuttings being planted from 1′ 6″ to 2′ apart. The furrows are then covered in and irrigation water is supplied as necessary during the hot weather, a bag of crude oil emulsion being placed in the channel to keep down white-ant attacks. When the plants are established the clumps are thinned out from 2′ to 3′ apart. After each irrigation the land is hoed lightly to conserve the moisture. When the monsoon has become established and the land is becoming sodden and water-logged the canes are ridged up with the earth from the ridges in such a way that the ridges become trenches and the trenches ridges. The land is hoed and weeded some 2 or 3 times and finally dug up before it has had time to dry out at the close of the monsoon. The canes will be ready for harvest in January to March. They are not ratooned.

Pressure of other duties has made it very difficult to find time for this work so that it has been under the charge of a number of officers. During the seasons 1909-10 and 1910-11 the preliminary field observations were carried out by myself and Mr. D. Mukherji (Asst. Professor of Botany), who also made the mass selections for the 1910-11 crop. The single plants for the crop of 1911 were selected by me and examined in the laboratory by myself and Mr. A. C. Ghosh (Asst. Economic Botanist), who selected and examined the plants selected for the 1912 crop. During 1911 a number of field observations were made by myself, but my appointment as Principal of the Sabour Agricultural College in June 1911 has since made it very difficult for me to give more than a limited time to the work. The 1912 crop was very thoroughly examined by Mr. Basu in the spring of 1913, Mr. Basu's results being checked by myself. In 1914 the 1913 crop was checked by Mr. Basu and myself. It is due to the thoroughness with which Mr. Basu carried out his portion of the work and to the grasp which he obtained of the characters of the cane that it has been possible to prepare this paper. E. J. W.

II.—Distinguishing Characters of Cane Varieties.

(a) Field Characters.

Habit.—Under this head observations were made on the general appearance of the stools in the field. Cane varieties differ very considerably in habit, all the canes of each stool of some varieties being erect and close packed while other varieties may be ascending or decumbent. Even among the short bushy canes, in which group the varieties are very similar, the varieties *Poraya*, *Paunri* and *Rheora* are slightly more spreading than the rest of the group which are almost erect. In the tall canes the differences of habit are very much more marked, the *Baraukha* type being typically erect, the *Maneria* type more spreading, and varieties of the *Bansa* type are usually lying on the ground with the tops of the canes only erect. In most varieties the first young shoots are upright or slightly spreading but in the case of *Khari* and *Nargori* the young shoots are very markedly spreading and in some cases almost horizontal.

Persistence of dry Leaves and Sheaths.—An examination of the varietal plots from December onwards shows that different varieties of cane retain their lower dried leaves and leaf sheaths to a greater or less extent. In the case of the *Buxaria* group the whole length of each cane is completely covered by the persistent sheaths, in the taller varieties however the sheaths are not persistent to the same extent, and in most of the "thick" foreign varieties the canes are found to be bare of leaves. While these differences may be due to some inherited character of the cane, it is possible that the persistence of the leaves in the *Buxaria* group may be due to the shortness of the cane and the high tillering which prevent the wind from getting at the old dry leaves. In the thick canes the small number of tillers and their slightly spreading habit may enable the wind to detach the leaves more easily. In the taller varieties the elongation of the aerial roots would probably help to detach the sheaths.

Tillering.—The examination of this character was usually carried out at harvest time, and to obtain comparative figures the total number of mature canes (excluding young shoots) in as many bushes as possible was counted. It will be seen from the table given below that the short bushy canes have a high tillering capacity (9—16) though the thicker members of the group, *Buxaria*, *Hemja*, *Paunri* and *Poraya* fall considerably short of the average (13—16) attained by the thinner varieties *Lewari*, *Rheora*, and *Mango*. The tall canes all tiller to about the same extent and give results about equal to the thicker members of the *Buxaria* group (*viz.*, 9—10). *Nargori* differs from the rest of the tall canes in its higher tillering capacity (13). The thick imported canes give a very low average (5—6). It would appear therefore that the tillering capacity varies inversely with the thickness of the cane.

Table showing the tillering of different varieties of cane.

No.	Variety.	No. of stools.	No. of canes.	Average.	No.	Variety.	No. of stools.	No. of canes.	Average.
	Group 1.					*Group* 6—(contd).			
1	Buxaria	110	992	9	19	Lata	347	3,817	11
2	Hemja	128	1,256	10	20	Khagri	36*	433	12
3	Mango	325	4,179	13	21	Ketari No. III.	40*	474	12
4	Lewari	529	7,952	15	22	Chynia No. II.	14	191	13·5
5	Rheora	299	4,951	16·5		*Group* 7.			
6	Paunri	254	3,072	12					
7	Poraya	254	2,562	10	23	Khelia	181	1,388	7·5
	Group 2.					*Group* 8.			
8	Shakarchynia	413	5,680	14	24	Striped Bansa	16	106	7
	Group 3.					*Miscellaneous "thick" canes.*			
9	Bansa	264	2,259	8·5					
10	Ketari No. I.	95	759	8	25	Kajla	49	281	6
	Group 4.				26	Red Mauritius	22	110	5
					27	Bombay	51	260	5
11	Baraukha	75	760	10	28	Red Bombay.	56	288	5
12	Kewali	39	396	10	29	Bhuri	31	185	6
13	Nargori	238	3,255	13·5	30	Red Java	43	183	4
14	Ketari No II.	66	519	8	31	Red Tanna	2	11	5
15	Chynia No. I.	69	630	9	32	White Mauritius.	18	107	6
	Group 5.				33	Dhalsunder	22	122	5·5
16	Khari	180	1,482	8	34	Benarasia-Nepali.	11	68	6
	Group 6.				35	Shamshara	23	101	4·5
17	Maneria	196	1,931	10	36	Sukli	42*	341	8
18	Panshahi	252	2,441	10	37	Puri	37*	288	8

* Observations of 1911 (crop of 1910) on account of poor crop in 1912. These observations were made by a different observer and are usually rather higher.

(b) CHARACTERS OF STRIPPED CANE.

In examining the canes under the following heads immature canes and diseased and dried up canes as well as exceptionally thick canes or unusually thin canes have been neglected. Efforts have always been made to describe what have been considered to be the average canes of a particular variety and for this purpose generally from 150—200 canes of each variety have been cut and 100 average canes have been selected from these for examination, of which ten have been again selected for the detailed measurements. The length and thickness of the various cane varieties vary according to the climatic and other conditions of each year.

GENERAL APPEARANCE OF CANE.—Under this head observations have been made as to whether the canes are straight or curved, and a general idea as to the thickness and length of the cane has been recorded.

LENGTH.—This measurement is taken from the base of the mature cane at the ground level to the base of the green sheath at or about the topmost joint of the cane. It will be seen from the figures in Appendix II, Column 6, that the average of the short bushy canes varied in length from 4′ 6″ to 6′. *Shakarchynia* is about 6′ and the tall canes vary from 7′ to 9′. The thick canes vary from 4′ to 7′, their length being much influenced by the character of the season, cultivation, etc.

NUMBER OF INTERNODES.—The figures for this character were obtained by counting the internodes in the ten typical canes used for obtaining the measurements of length, etc. In the case of the short bushy canes the number of internodes will be about 30 in the case of a cane 5′ long. In the tall canes of the *Bansa* and *Baraukha* types the number of internodes is usually between 30 and 40, while in the case of the *Maneria* and *Khari* types the internodes vary from 26 to 35 and in *Khelia* there are usually not more than 30 internodes.

LENGTH OF INTERNODES.—It was originally expected that it would be possible to obtain figures for this character by dividing

the length of the cane by the number of internodes. It was found, however, that the figures obtained were unsatisfactory on account of the fact that in most canes the internodes at the base and apex are both very short, while the individuality of the cane is shown only in the length of the internodes in the middle of the cane. It was therefore decided to obtain the figures for the lengths of the internodes by finding the middle node of the cane and measuring 5 internodes on each side of it, *i.e.*, 10 internodes in all, and then taking the average of these for the 10 canes examined as the average length of internode for the variety. In the short bushy canes the average length of internode is found to be about 3″ while in *Shakarchynia* it is slightly longer. In the case of the tall canes however there are marked differences, the *Bansa* and *Baraukha* types having internodes varying from 3″ to 4″, while in *Maneria* and *Khari* types they usually vary from 4″ to 5″ in length. In the case of *Khelia* also the average length of the internodes varies from 5″ to 6″. It will be seen from the above that in these last three tall varieties the longer internodes make up for their smaller number.

Thickness of Cane.—To determine the thickness and shape of the cane three measurements have been taken of each cane examined. In the first place the diameter of the tenth node from the base was taken, in the second place the diameter of the middle of the internode above the tenth node was taken, and in the third place the diameter of the narrowest part of this internode (usually in the neighbourhood of the "waxband") was measured. In taking all these observations the bud remained uppermost and the measurements were made at right angles to it. In cases where the tenth node was much covered with roots the ninth or eleventh was taken.

The observations given in Appendix II are those made in 1913, and they are generally supported by those of previous years. The thickness of the cane in each strain varies from year to year in accordance with season and cultivation and a certain amount of difference may exist between the thickness of two strains of a variety, which differences would appear in some cases to be

inherited. It would therefore appear that the thickness of the cane is not by itself a useful critical character. It has been found however that in spite of this the varieties of a group usually maintain their relative positions as regards thickness of cane.

SHAPE OF CANE.—In addition to recording the thickness of the cane the above observations were intended chiefly to show clearly the relation of the diameter of the node to that of the internode and the shape of the internode, whether straight, tapering upwards or barrel shaped. As regards the general shape of the cane, in the case of the short bushy canes and also *Shakarchynia* the nodes and internodes are of uniform thickness. Of the tall canes the *Bansa* type has least difference in thickness between the nodes and internodes. In the *Maneria* and *Khari* types the difference in diameter is slightly greater than in *Bansa*, but owing to the greater length of the internodes the difference is not very conspicuous. In the case of *Khari* the internodes taper upwards throughout their length. In the *Baraukha* group the difference in diameter between the nodes and internodes is most prominent. The thick canes are usually over 1″ in diameter, and in the Bombay group have a well marked barrel shape. The varieties appear to vary less in shape than in diameter from year to year.

COLOUR AND MARKINGS OF CANE.—The colour has been expressed in general terms only. At one time an attempt was made to compare all the colours with the standard on the Colour Chart of the French Chrysanthemum Society but the great number of minor variations in colour found in any one variety made it doubtful whether the results would be commensurate with the labour involved. Of the narrower-leaved greenish canes the *Buxaria*, *Shakarchynia* and *Bansa* groups are distinguished by the brighter yellow colour of their canes. The *Baraukha* group on the other hand have canes of a dirty yellow green colour, *Nargori* being slightly brighter than the other varieties. The *Maneria* group is intermediate between the two groups mentioned above. *Khari* is similar to the *Maneria* group except that some of the internodes may have a reddish tint in places. In the case of all these green varieties the immature

canes when exposed to the sun usually develop a reddish colour. The striped canes are represented only by striped *Bansa.* Of the larger-leaved "thick" canes the colour of the cane is greenish in the case of White Mauritius, *Dhalsunder*, *Benaresia-Nepali*, *Shamshara*, *Sukli* and *Puri*; that of Red Java and Red Tanna is greenish yellow with a reddish tinge, *Khelia* is yellowish red to reddish, Bombay, Red Bombay, and *Bhuri* are red to chocolate, while Red Mauritius and *Kajla* are red to purple. *Bansa* and *Ketari* No. I are distinguished from other varieties by the fact that the mature canes are marked with fine brown lines running down the nodes or internodes (*vide* Plate II).

Development of Aerial Roots.—There are marked differences between cane varieties as regards the development of aerial roots, some varieties produce practically none, others develop roots up to about 6 nodes with occasional scattered roots higher up and others again produce roots up to two-thirds or even three-fourths of their length. The short bushy canes are practically devoid of aerial roots. In *Shakarchynia* they are developed up to about 6 nodes and scattered nodes higher up the cane very occasionally produce roots. Of the tall canes the *Bansa* and *Maneria* groups develop aerial roots usually up to 6 nodes, while in the *Baraukha* and *Khari* groups aerial roots are developed up to two-thirds or three-fourths of the length of the cane. In *Maneria* the nodes have prominent tubercles when the roots are not developed. In the thick broader-leaved canes aerial roots are only developed at the lowest six nodes in *Khelia*, while in *Kajla*, White and Red Mauritius, the Bombay group, Red Java and Red Tanna the roots are usually confined to three or four nodes only. In *Dhalsunder*, *Benaresia-Nepali* and *Shamshara* the roots are usually confined to the lowest three or four nodes, but scattered roots may also be found higher up. In *Sukli* and *Puri* aerial roots are generally developed right up the cane.

Wax.—The presence of wax is well marked all over the internodes of the short bushy canes with the result that their colour is altered from yellow or green to honey yellow and sea green. In

the other narrow leaved varieties wax is usually present in quantity in the wax band and elsewhere to a less extent. In the tall varieties the wax is often blackened, this being due apparently to its oxidization as no traces of fungi have been found. In the broader leaved "thick" varieties wax is present to a larger extent in *Kajla* and the Bombay group.

COLOUR BAND.—This term has been applied to the portion of the cane immediately above the nodes (*vide* Plate I), which in some varieties can be distinguished by its deeper colour. The colour band is well shown in the coloured plate of *Maneria* and *Bansa* (Plate II). In the short bushy canes no colour band is distinguishable, in *Shakarchynia* only a very narrow band is present; of the tall canes, the colour band is indistinct in the *Baraukha* type, narrow in *Bansa*, medium in *Maneria* and broad in *Khari*. In the case of *Khari* the band is always very broad and deep brown. In striped *Bansa* the band is present. Of the "thick" broad leaved canes the band is present in *Kajla*, *Khelia* and Red Java, not well marked in *Shamshara* and inconspicuous in the Bombay type and Red Mauritius.

BUDS.—The shape and size of the buds have only been referred to in a very general way. The amount of sprouting varies considerably in different varieties and is probably due to the extent to which the white borer attacks that particular variety (*vide* Section on diseases below.)

(c) LEAF CHARACTERS.

GENERAL APPEARANCE.—In some varieties, notably the short bushy canes and the *Bansa* group, the leaves remain straight with a slight bend at the tip; while others, such as the thick canes and the *Baraukha* and *Maneria* group have their leaves bent over at about the middle. The leaves of *Shakarchynia* are straight to the tip. In the short bushy canes and the thick canes the young sheaths are shorter and so the ligular band of the younger leaves are lower than those of the older leaves and are therefore hidden between the older leaf sheaths, whereas in the *Maneria* and *Baraukha* group the sheaths of the younger leaves are equally developed and

ligular bands emerge from between the lower leaf sheaths, except in the case of the 3 or 4 youngest leaves at the very top of the cane.[1] *Shakarchynia* is intermediate between these groups with the result that a large number of leaves spread outwards from one point in a fan-like manner.

SIZE.—The observations of these characters were taken at harvest time on the leaves to be found in the crown of the cane. They refer to the largest leaves to be found at that time, at which it was difficult to obtain green unbroken leaves. The leaves attain their largest size in the thick canes, the largest leaf being 5′ by 2·5″ in Java and Tanna. The smallest leaves are found in *Shakarchynia* (2′ 6″ by 1″). In the tall canes they are of medium size (3′ 0″ to 3′ 6″ by 1″ to 1·5″), and differ from those of the short bushy canes only in their breadth.

COLOUR.—When looking at the plots of the cane varieties at a distance it is usually possible to observe some difference between the colour of the foliage of the different groups. The thick varieties have a markedly lighter or yellower colour than the others, the short bushy varieties being slightly lighter in colour than the tall canes. Of the tall canes the *Maneria* group has somewhat lighter coloured leaves than the *Baraukha* group.

LIGULAR BAND.—This term has been applied to two patches of colour which appear at the junction of the leaf blade and sheath on the outer side of the leaf over the ligule (*vide* Plate I).

This band varies from yellowish green to deep red or brown. In the case of the short bushy canes it is lighter than the surrounding region. In *Shakarchynia* it is dirty yellow brown. In the tall canes it varies from pale yellow in the *Baraukha* group, through faintly reddish yellow in *Bansa*, brownish yellow in *Khari*, to reddish in *Maneria*. Among the thick canes also the ligular band varies from yellow in *Shamshara* and *Benaresia-Nepali* to brownish in the Bombay group and Mauritius. During some chemical selection experiments carried out by Mr. Taylor in 1910 we were able to trace

[1] *Vide* Plate III.

some correlation between the colour of the juice and that of the ligular band in *Khari* and *Maneria* but it has not been possible to follow up this observation.

(*d*) OTHER CHARACTERS.

WEIGHT OF 100 CANES.—In order to ensure that average canes were used for weighing, 100 average canes were selected from the 150 to 200 canes harvested for examination. In some varieties the canes were found to differ markedly in thickness and in these canes the proportion of thick to thin canes in the bulk sample was determined and the 100 canes required for weighing were selected according to these proportions. It was not possible to obtain 100 canes of the thick varieties so that 10 average canes only were measured and the results multiplied up. In all cases the canes were stripped and the crowns cut off to within a few inches of the top of the cane.

FLOWERING OF CANE.—It would appear that cane only flowers at Sabour in exceptional years. The list below shows the varieties that have been observed in flower at Sabour, together with the year in which the observation was made—

Chynia No. 1	1911.
Khari	1909, 1910, 1911, 1912.
Khelia	1911.
Maneria	1911.
Panshahi	1911.
Shakarchynia	1911.

It will be seen that *Khari* usually produces some flowers, but did not do so at all in December 1913. The year 1911 was a particularly favourable year for flowering. *Khelia* was the only variety in which the anthers dehisced, so that it may be useful for breeding purposes in this part of India. In the case of *Chynia* the flowers hardly emerged from the leaf sheath.

DISEASES.—The two principal fungus diseases are smut and red rot. Smut is usually only found in the *Khari* variety. Red

rot attacks all the tall canes but is less prevalent in the *Bansa* group and *Khari* than in the *Baraukha* and *Maneria* groups. The short bushy canes are more or less immune to red rot. Of the thick canes the Bombay group are usually attacked by red rot.

The chief insect pests are the two borers[1] and of these the moth borer is responsible for the bulk of the damage. Some observations were made in March 1914 on the damage done by white borer and in the crop examined it was found that the thick canes were usually very little attacked (0—40 per cent.), the tall canes usually attacked to an extent of about 40—60 per cent. and the short bushy canes to a very variable extent (4—70 per cent.). While no definite conclusions can be arrived at as the result of these observations, it is of interest to note that in many cases the badly attacked and immune varieties were next each other, so that it would seem that immunity to attack by borers may be a varietal characteristic.

Chemical Characters (contributed by C. Somers Taylor).

It will be of interest to note how far the chemical properties of a cane are connected with its botanical characters and to see whether the canes may be grouped chemically and whether these groups agree with the botanical ones.

In 1910 some measurements were made which led to the conclusion that the periods of maturity differed very greatly among the different canes grown at Sabour. The only canes that grew well at Sabour were the dwarf canes and the tall reed-like canes. Of these it was found that while there was practically no change in the saccharose content of the juice of *Khari* and *Shakarchynia*, the dwarf canes (with the exception of *Lewari* which was stunted) showed a large increase even up to March.

The canes known as *Maneria* and *Panshahi* showed a definite cessation of ripening in between these two dates. The thick canes

[1] Moth borer = *Chilo simplex*.
White borer = *Scirpophaga auriflua*.

with the exception of *Dhalsunder* cannot be considered ever to have grown sufficiently well at Sabour for reliance to be placed on saccharose determinations, the results of which depend so largely on the growth of the cane as a factor. It is probable, however, that they ripen at a time intermediate between that of *Khari* and the dwarf canes. Incidentally it may be remarked here that during the period under review (1910-1913) there would appear to be least loss on all the canes grown at Sabour by cutting in February and early March, while *Khari* and *Shakarchynia* could be cut in January without serious loss. The dwarf canes when properly grown should never be cut before February. When badly grown they frequently ripen earlier.

At first sight, therefore, *Khari* and *Shakarchynia* would appear to stand in a class by themselves as early ripeners while *Maneria* and *Panshahi* would be typical of another class and the dwarf canes of a final late ripening class. Further observations showed, however, that these canes differed in other ways that could be chemically measured. It was found in 1910 that with the same mill, different varieties gave a far different extraction, *i.e.*, some varieties showed more spongy megass than others. These observations were confirmed in 1912-13 and the results were published in *Pusa Bulletin* No. 37 of 1913.

Taking the two early ripening canes which were provisionally put into the same group we obtain the following figures :—

Cane.	Average fibre on cane.	Average fibre on megass.	Calculated extraction factor 1913.
Khari	16·41	46·3	79·6
Shakarchynia	13·94	42·1	80·1

From these figures we see that *Khari* is a much more fibrous cane than *Shakarchynia* and that it has much the same extraction factor.

Comparing these results with those of *Panshahi* and *Maneria* we obtain the following figures :—

Cane.	Average fibre on cane.	Average fibre on megass.	Calculated extraction factor, 1913.
Panshahi	12·71	41·9	82·2
Maneria	12·26	41·3	82·4

Again comparing the results obtained from the dwarf canes we find :—

Cane.	Average fibre on cane.	Average fibre on megass.	Calculated extraction factor.
Buxaria	11·42	34·2	77·5
Poraya	11·74	32·6	74·8
Paunri	12·95	33·5	72·5
Rheora	12·97	33·6	72·6
Hemja	13·03	34·1	73·3
Mango	13·16	34·2	72·9

It will be seen that a characteristic of this group is a medium content of a highly absorbent fibre which, except in the case of *Buxaria*, gave extraction factors below 75 per cent.

In spite however of the fact that the cane known as *Buxaria* showed a higher extraction factor than the rest it has been included in the group as all its other characteristics are the same.

The canes known as *Khagri* and *Chynia II* are doubtful as regards their place in a chemical classification. They have never ripened well at Sabour and it is difficult to say much about them at present. Their fibre content is similar to those of *Panshahi* and *Maneria* with which they have been grouped botanically, but their extraction appeared to be lower.

There is no doubt however that four definite groups can be obtained from chemical considerations that coincide with four of the groups into which the canes have been classed botanically.

These groups are as follows :—

1. Late ripening, medium fibre, low extraction factor. This corresponds with Botanical group No. 1[1].

[1] The classification of the canes into groups will be found in Section IV, pp. 146-50.

2. Early ripening, medium fibre, high extraction factor, corresponding with Botanical group No. 2.

3. Early ripening, high fibre, high extraction factor, corresponding with Botanical group No. 5.

4. Medium early ripening, medium fibre, high extraction factor, corresponding with Botanical group No. 6.

The ripening of this last group can definitely be measured only in the case of *Maneria* and *Panshahi*, as *Lata* and *Khagri* did not grow well when the measurements were made, and *Kelari* and *Chynia* were not then separated into different groups.

The measurements of the periods of maturity were not made with pure lines. It is hoped that with the greater facilities that should be afforded by a properly equipped sugar station further observations may be made on the pure lines bred by the Economic Botanist.

We may conclude therefore that the chemical and botanical characters of the varieties are closely allied. There is no doubt that the most constant of the former is connected with the quality of its fibre. Observations from year to year show very little difference in the order of extraction of each cane, which is probably a definite characteristic of the cane itself depending on some botanical character.

A table is appended which shows tentatively the grouping of the canes both chemically and botanically.

Group.	Ripens.	Extraction factor in 1913.	Fibre on cane in 1913.
I	Late	74·0± ·5 Low	12·46±·21 Medium
II	Early	80·1±1·4 High	13·04±·59 Medium
III	Doubtful	77·7±1·0 Medium	14·64±·42 High
IV	Probably early	76·8± ·6 Medium	15·68±·27 High
V	Early	79·6±1·4 High	16·41±·59 High
VI	Medium (between II & I)	79·3±1·6 High	12·27±·27 Medium
VII	Doubtful	84·8±1·4 High	13·10±·59 Medium
VIII	Never gives sweet juice under Sabour conditions.	77·5±1·4 Medium	12·74±·59 Medium
Miscellaneous.	Probably medium but these canes do not grow well under Sabour conditions.	High, varies from 79·4 to 89·1, all but one above 80.	The fibre of these canes varies from 8·59% in the case of Red-Bombay to 15·36 in the case of Red-Tanna so that an average does not give much information.

Concluding Remarks.—It will be sufficiently clear from the above account of the characters of the cane that attention has not been paid so much to minute botanical characters as to agricultural characters likely to be of use for identifying canes in the field, or which are likely to determine the value of the cane to the agriculturist. The smallness of the area at our disposal here has made it impossible to grow the canes on a field scale but the work will be continued by a study of the yield, quality of gur and chemical characters of the cane at Sipaya. The inheritance of thickness in a number of pure cultures of one variety may repay study as may the histological differences of the varieties.

III.—Description of cane varieties cultivated at Sabour.

1. Buxaria.—*Clumps* short bushy, canes slightly spreading, completely covered with persistent dry leaves and sheaths; *Tillering* 9 on an average, maximum observed 23. *Canes* typically straight, short and fairly thick, length 4′ to 6′, number of internodes varies according to the length of the canes, a cane 5 ft. long has approximately 30 internodes, length of internodes in the middle of the cane 3″ on an average. *Thickness* more or less uniform in the node, internode and top of the internode which varies from 0·8″ to 1″ in diameter. *Colour* honey yellow to sea green in varying proportion with patches of brown. *Wax* thickly present all over the cane, more thickly on the wax band just below the node. *Rooting band* inconspicuous; *aerial roots* typically absent; *Dormant buds* stout and of equal length and breadth; sprouting rare; *colour band* not well defined. *Leaves* more or less upright, bending at the top, size of blade 3′ 6″ by 1·5″, colour of leaves light green to dark green, *ligular band* slightly lighter in colour than the surrounding region, yellowish green under a deposit of wax. 100 average canes weigh 140 lbs.

This cane is not known to have flowered at Sabour and there is no evidence to show that it has flowered anywhere else in the Province. It is generally found to be free from the attacks of red rot or white borer and is on the whole a good clean cane.

2 Hemja.—*Clumps* short and dense, canes slightly spreading out like Buxaria, completely covered with dry persistent leaves and sheaths. *Tillering* 10, maximum observed 21. *Canes* short and fairly thick but not as straight as *Buxaria*, length 4′ to 6′, number of internodes 30 for a cane 5′ long, length of internodes 3″. *Thickness* more or less uniform in the node, internode and the

top of the internode varying from 0·8″ to 1″. The sheath scars are not usually at right angles to the length of the canes. *Colour* perhaps slightly greener than *Buxaria* with patches of brown as in *Buxaria*. *Wax* thickly present all over the cane to about the same extent as in *Buxaria*. *Rooting band* inconspicuous, *aerial roots* typically absent. *Dormant buds* similar to *Buxaria* and sometimes situated in grooves. Sprouting common from the top of the cane often due to attacks of white borer on the main shoot. *Colour band* not well defined. *Leaves* more or less upright bending at the top though not to the same extent as in *Buxaria*, size of blade 3′ 6″ long by 1″ broad, hence narrower than *Buxaria*, colour of leaves similar to *Buxaria*, *ligular band* yellowish green under a deposit of wax. Weight of 100 canes 139 lbs.

This cane has not flowered at Sabour and it is not known to us that it has flowered elsewhere. It is generally free from the attack of red rot but white borer is frequently found to damage the main shoot. It chiefly differs from *Buxaria* in having narrower leaves, darker colour and sprouting buds.

3. MANGO.—*Clumps* short and dense, canes slightly spreading, completely covered with persistent dry leaves and sheaths. *Tillering* 13, maximum observed 26; *canes* typically straight, short but rather thinner than Buxaria, *length* 4′ 6″ to 6′, number of internodes 30 in a 5′ cane, length of internodes 3″ in the middle of the cane. *Thickness* more or less uniform throughout the length of the cane 0·7″ to 0·8″ in diameter. *Colour* similar to *Buxaria*, being honey yellow to sea green with patches of brown. *Wax* thickly present all over the cane. *Rooting band* inconspicuous, *aerial roots* typically absent. *Dormant buds* stout, conical and almost of equal length and breadth, sprouting occasional, *colour band* not well defined. *Leaves* more or less upright with a bend at the top, size of blade 3′ 6″ by 1″, hence similar to *Hemja* and narrower than *Buxaria*; colour of leaves light to dark green, *ligular band* yellowish green. Weight of 100 canes 94 lbs.

This cane has not flowered at Sabour and has not been reported to have flowered anywhere else. It is comparatively free from

the attack of red rot, but is liable to the attack of white borer. It looks like *Buxaria*, but is thinner.

4. LEWARI.—*Clumps* short and dense, canes spreading, completely covered with dry persistent leaves and sheaths. *Tillering* 15, maximum observed 30. *Canes* straight, short and rather thin, as compared with *Buxaria*, length 5′ to 6′, number of internodes about the same as in *Mango;* length of internodes 3″ in the middle of the canes. *Thickness* more or less uniform throughout the length of the cane being 0·6″ to 0·7″; *Colour* similar to *Buxaria* between honey yellow to sea green with patches of brown. *Wax* thickly present all over the cane. *Rooting band* inconspicuous; *aerial roots* typically absent. *Dormant buds* stout and conical and of equal length and breadth, sprouting common from the upper portion of the cane. *Colour band* not well defined. *Leaves* similar to *Mango*, size of blade 3′ 6″ by 1″, colour light green, *ligular band* yellowish green, under a deposit of wax. Weight of 100 canes 70 lbs.

This cane is very similar to *Mango*, from which it is hardly distinguishable, if anything it is thinner. It has not flowered at Sabour and is not reported to have flowered anywhere else. It is generally free from attacks of red rot, but is very liable to the attacks of white borer.

5. RHEORA.—*Clumps* slightly taller than the above, dense, canes slightly spreading, completely covered with dry persistent leaves and sheaths. *Tillering* 16, maximum obtained 34. *Canes* slightly curved, somewhat taller than *Buxaria* but thinner, length $5\frac{1}{2}'$ to $6\frac{1}{2}'$, number of internodes varies from 25 to 30 in average canes, length of internode about 3″ in the middle of the canes. *Thickness* more or less uniform throughout the cane, 0·6″ to 0·8″ diameter. *Colour* similar to *Buxaria* honey yellow to sea green with patches of brown. *Wax* present all over the cane. *Rooting band* inconspicuous; *aerial roots* absent. *Dormant buds* of equal length and breadth, stout, sprouting common from the upper part of the cane. *Colour band* not well defined. *Leaves* similar to *Mango*, size of blade 3′ 6″ by 1″, colour light green, *ligular band* yellowish green, under a deposit of wax. Weight of 100 canes 102 lbs.

This cane appears to be superior to *Mango* and *Lewari* and taller, but thinner than *Buxaria*. It has not flowered at Sabour, and has not been reported to have flowered anywhere else. It is only slightly liable to attacks of red rot, but white borer is found to damage the main shoot frequently.

6. PAUNRI.—*Clumps* similar to *Rheora*, canes slightly spreading, completely covered by dry persistent leaves and sheaths. *Tillering* 12, maximum observed 23; *canes* not as straight as *Buxaria* but slightly curved, length 5′ to 6′, number of internodes about 30 in average canes, length of internodes 3″. *Thickness* more or less uniform throughout, the length of the cane being 0·7″ to 0·9″. *Colour* similar to *Buxaria* honey yellow to sea green with patches of brown. *Wax* present all over the cane. *Rooting band* inconspicuous, *aerial roots* absent; *Dormant buds* similar to the above, sprouting common from the upper half of the cane, *colour band* not well marked. *Leaves* similar to the above, *size of blade* 3′ 6″ by 1″, colour light green, *ligular band* yellowish green under a deposit of wax. Weight of 100 canes 114 lbs.

This cane has not flowered at Sabour and has not been reported to have flowered anywhere in the Province. It is generally free from the attacks of red rot, but is very liable to the attacks of white borer which stimulates the upper buds to sprout. A very similar cane to the above.

7. PORAYA.—*Clumps* tall and spreading, almost laid on the ground, canes completely covered by dry persistent leaves and sheaths. *Tillering* 10, maximum obtained 25; *canes* slightly curved with a bend at the top, length $5\frac{1}{2}'$ to $6\frac{1}{2}'$ or even 7 ft., number of internodes about 30 in a 6′ cane, length of internodes slightly over 3″. *Thickness* more or less uniform throughout the length of the cane, if anything the nodes are slightly thicker, 0·8″ to 1″ in diameter. *Colour* similar to *Buxaria* sea green to honey yellow with patches of brown. *Wax* present all over the cane. *Rooting band* inconspicuous, *aerial roots* absent; *Dormant buds* similar to above, sprouting common from the top of the cane, *colour*

band not well defined. *Leaves* larger than the above, size of blade 3′ 6″ by 1·5″, colour light to dark green, *ligular band* yellowish green. Weight of 100 canes 168 lbs.

This cane has not flowered at Sabour and has not been reported to have flowered anywhere else in the Province. It is more or less free from the attack of red rot, but is somewhat liable to attacks of white borer though not to the same extent as *Hemja*, *Mango*, etc.

8. SHAKARCHYNIA.—*Clumps* tall and spreading, sometimes laid on the ground, canes covered with persistent dry sheaths. *Tillering* 14, maximum observed 30. *Canes* slightly curved, length 6′ to 7′, number of internodes varies generally from 24 to 30, length of internodes 3·3″. *Thickness* more or less uniform throughout the length of the cane if anything slightly thicker at the nodes, diameter 0·6″, *colour* yellow green with removable black incrustations, *wax* present in the wax band, scanty in other parts of the cane. *Rooting band* inconspicuous, *aerial roots* well developed in the lowest 4 to 6 nodes, sometimes extending as high as the middle of the cane, *dormant buds* flat and almost circular, sprouting rarely from the top of the cane. *Colour band* narrow, yellow brown. *Leaves* short and narrow, typically straight and spread out in the form of a fan, size of blade 2′ 6″ by 1″, colour light green. *Ligular band* dirty yellow brown under a deposit of wax. Weight of 100 canes 84 lbs.

This cane flowered at Sabour in 1911, but only a few pollen grains were found. It is only slightly liable to attacks of red rot though white borer is sometimes present. It differs from the foregoing canes in many points which have been discussed in Section IV. Longitudinal cracks sometimes occur in the internodes.

9. BANSA.—*Clumps* tall, spreading, bending over or laid on the ground, canes indifferently covered by dry persistent leaves and sheaths. *Tillering* 8, maximum observed 20. *Canes* long, thin and more or less straight; length $7\frac{1}{2}'$ to $9\frac{1}{2}'$, number of internodes 30—40, length of internodes 3″—4″. *Thickness*, nodes 0·7″ to 0·9″, internodes 0·6″ to 0·8″ with a difference of about 0·1″ between the nodes and internodes. *Colour* bright yellow to yellow green, with

here and there removable black incrustation. *Wax* spread thinly all over the cane with a thick deposit on the wax band. *Rooting band* inconspicuous, *aerial roots* usually confined to about 6 nodes at the base, occasionally developed in some nodes in the middle of the cane. *Dormant buds* are flat or stout, sprouting from the top of the cane. *Colour band* a distinct yellow brown, colour band present. *Leaves* small and erect with tips bending over. Size of blade about 3′ by 1·5″, *colour* light green, *ligular band* faintly reddish brown, the red being often on the border. Weight of 100 canes 145 lbs.

This cane differs from the foregoing in many important points which have been described in Section IV. It is not known to flower, and is only slightly liable to red rot, though white borer is often found to attack the main shoot. It has some characteristic streaks, both in the internodes and the nodes (*vide* Plate II).

10. KETARI No. 1.—*Clumps* tall, spreading or bending over or laid on the ground, *canes* indifferently covered by dry persistent leaves and sheaths. *Tillering* 8, maximum observed 19. *Canes* more or less straight, tall and thin. *Length* about 7 feet, number of internodes 28—34, length of internodes 3″—4″. *Thickness*, nodes 0·6″ to 0·8″, internodes 9·5″ to 0·7″, with a difference of about 0·1″ between the nodes and the internodes. *Colour* similar to *Bansa*, bright yellow to yellow green, with removable black incrustation. *Wax* spread thinly all over the cane and more thickly in the wax band. *Rooting band* inconspicuous, *aerial roots* usually confined to the lowest 6 nodes occasionally developed higher up the cane. *Dormant buds* flat or stout, sprouting from the top of the cane. *Colour band* yellow brown and distinct. *Leaves* small and erect with tips bent over, size of blades 2′ 6″—3′ by 1·3″ to 1·5″; colour light green, *ligular band* faintly reddish brown. Weight of 100 canes 102 lbs.

This cane appears very similar to *Bansa* though somewhat poorer. It has also the brown streaks found in the nodes and internodes of *Bansa*. It is not known to flower, and is generally

free from the attacks of red rot, though white borer is commonly found.

11. Baraukha.—*Clumps* tall, growing almost upright, dried leaves and sheaths indifferently covering the canes though many internodes are exposed. *Tillering* 10, maximum obtained 20. *Canes* almost straight, tall and thin, length 7′ to 9′, number of internodes variable between 30 and 40, length of internodes 3″—4″. *Thickness*, nodes 0·7″ to 0·9″, internodes 0·6″ to 0·8″ and top of internodes slightly less than the middle, hence the internodes appear gradually tapering from the bottom to the top, a difference of over 0·1″ is noticeable between the nodes and the internodes. *Colour* dirty yellow green with black incrustations. *Wax* present but not very clear. *Rooting band* swollen, *aerial roots* very common up to two-thirds of the length of the cane or even more, occasionally suppressed in some nodes. *Dormant buds* placed flatly, sprouting common due to attacks of borer. *Colour band* inconspicuously present. *Leaves* bent over from the middle, size of blade about 3′ by 1·5″, colour dark green with a narrow edge of red in some, *ligular band* yellowish green. Weight of 100 canes 106 lbs.

This cane differs from the *Bansa* type in many important characters which will be found in Section IV. It is said to have flowered at Patna in 1911, but has not been found in flower at Sabour. It is very liable to attacks of red rot and white borer.

12. Kewali.—*Clumps* tall and almost upright. Cane indifferently covered by persistent dry leaves and sheaths, but exposed in some parts. *Tillering* 9, maximum obtained 17. *Canes* almost straight, tall and thin, length about 8′, number of internodes 30—40, length of internodes 3″—4″. *Thickness*, nodes 0·6 to 0·8″, internodes 0·5″ to 0·7″, with a difference of more than 0·1″ between the nodes and the internodes. *Colour* dirty yellow green with black incrustations. *Wax* present in some places but not very clear. *Rooting band* swollen, *aerial roots* present up to about two-thirds of the length of the canes, occasionally suppressed in some nodes. *Dormant buds* flat, sprouting from the top due to borer.

Colour band brownish, inconspicuous. *Leaves* bent over from the middle, size of blade about 3′ by 1·5″, colour dark green with sometimes a reddish border. *Ligular band* yellowish green. Weight of 100 canes 106 lbs.

This cane hardly differs from *Baraukha*. It has not flowered at Sabour and has not been reported to have flowered anywhere else in the Province. It is as liable to red rot and white borer as *Baraukha*.

13. NARGORI.—*Clumps* tall, almost upright, but at first growing in a slightly spreading manner. Canes indifferently covered by dried leaves and sheaths. *Tillering* 13, maximum obtained 30. *Canes* almost straight, tall and thin, length 7½′ to 8½′, number of internodes 30—40, length of internodes 3″—4″. *Thickness*, nodes 0·6″ to 0·8″, internodes 0·5″ to 0·7″, with a difference of more than 0·1″ between the nodes and the internodes. *Colour* slightly brighter than *Baraukha*, the yellow being more marked, black incrustations present. *Wax* scanty. *Rooting band* swollen, *aerial roots* very common up to two-thirds or more of the length of the cane. *Dormant buds* flat, sprouting from the top. *Colour band* brownish. *Leaves* bent over from the middle, size of blade 3′ by 1·5″, colour dark green, *ligular band* yellowish green. Weight of 100 canes 104 lbs.

This cane looks very similar to *Baraukha*, but somewhat brighter in colour, and has a slightly better tillering capacity. It has not flowered at Sabour and has not been reported to have flowered anywhere else in the Province. It is liable to attacks by red rot and white borer. The young canes grow almost like *Khari* in a spreading manner.

14. KETARI NO. II.—*Clumps* tall, almost upright, canes indifferently covered by persistent dry leaves and sheaths. *Tillering* 8, maximum obtained 20. *Canes* almost straight, tall and thin, length 7′ to 9′, number of internodes 30—40, length of internodes 3″—4″. *Thickness*, nodes 0·7″ to 0·9″, internodes 0·6″ to 0·8″, with a difference of more than 0·1″ between the nodes and the inter-

nodes. *Colour* dirty yellow green with black incrustation. *Wax* scanty and not very clear. *Rooting band* swollen, *aerial roots* very common up to two-thirds of the length of the cane. *Dormant buds* flat, sprouting common from the top of the cane. *Colour band* yellow brown. *Leaves* bent over from the middle of the cane, size of blade 3′ by 1·5″, colour dark green, *ligular band* yellowish green. Weight of 100 canes 106 lbs.

This cane is hardly distinguishable from *Baraukha* or *Kewali*. It has not flowered at Sabour or anywhere else that we know of. It is liable to attacks of red rot and white borer.

15. CHYNIA NO. I.—*Clumps* tall and almost upright, canes covered with persistent leaves and sheaths. *Tillering* 9, maximum obtained 23. *Canes* almost straight, tall and thin, *length* 7′ to 8′, number of internodes 30—40, length of internodes 3″—4″. *Thickness*, nodes 0·7″ to 0·9″, internodes 0·6″ to 0·8″, with a difference of more than 0·1″ between nodes and internodes. *Colour* dirty yellow green, with removable black incrustations; *wax* scanty and not very clear. *Rooting band* swollen, *aerial roots* present up to two-thirds of the length of the cane. *Dormant buds* flat, sprouting common from the top. *Colour band* brownish. *Leaves* bent over from the middle, size of blade 3′ by 1·5″, colour dark green, with narrow red border in some canes. *Ligular band* yellowish green. Weight of 100 canes 90 lbs.

This cane is hardly distinguishable from *Baraukha*, *Kewali* and *Ketari No. II*. It is very liable to red rot and white borer. *Chynia* is said to flower in different places and at Sabour; this type flowered in 1911.

16. KHARI.—*Clumps* tall, spreading or bending over, canes indifferently covered by dry persistent leaves and sheaths. *Tillering* 8, maximum obtained 18. *Canes* more or less straight, length $7\frac{1}{2}'$ to $8\frac{1}{2}'$, number of internodes 25—35, length of internodes 4″ to 5″. *Thickness*, nodes 0·7″ to 0·9″, internodes 0·7″ to 0·8″, and top of internodes 0·6″ to 0·8″, the difference between nodes and

internodes being less than 0·1″. *Colour* yellow green with patches of red, the yellow predominating, removable black incrustation present. *Wax* scanty except at wax band. *Rooting band* narrow, *aerial roots* developed high up the cane to nearly two-thirds or three-quarters of the length of the cane. *Dormant buds* flat and tapering, sprouting from the top. *Colour band* brownish, prominent. *Leaves* straight, bending at the top, size of blade 3′ 6″ by 1·5″; *colour* green, *ligular band* brownish. Weight of 100 canes 123 lbs.

This cane differs from the *Bansa* and *Baraukha* types in many respects which will be found in Section IV. It is the only cane which flowers frequently and is reported to have flowered in many localities. It is also very liable to smut disease and to attacks of white borer, but does not suffer much from red rot. The young canes grow in a peculiarly spreading manner.

17. MANERIA.—*Clumps* tall, spreading or bending over, canes indifferently covered with dry persistent leaves and sheaths. *Tillering* 10, maximum obtained 25. *Canes* slightly curved, length 8′ to 10′, number of internodes 25—35, length of internodes 4″—5″. *Thickness*, nodes 0·7″ to 0·9″, internodes 0·6″ to 0·8″, with a difference of about 0·1″ between the nodes and the internodes. *Colour* yellow green with patches of red, black incrustation present. *Wax* scanty. *Rooting band* broad and tubercled, *aerial roots* usually confined to about 6 lowest nodes though occasionally some nodes high up the cane give out aerial roots. *Dormant buds* flat and provided with two wing-like scales, sprouting from the top. *Colour band* present, yellow brown or greenish. *Leaves* bent over, medium, size of blade 3½′ by 1·7″, colour light green. *Ligular band* reddish. Weight of 100 canes 156 lbs.

This cane differs from the *Bansa* and the *Baraukha* types in many important points described in Section IV. It also differs from the *Khari* variety in certain respects. It flowered at Sabour in 1911, but the anthers which contained bright yellow pollen grains were not found to dehisce. It is liable to attacks of red rot and white borer.

18. PANSHAHI.—*Clumps* tall, spreading or bending over, canes indifferently covered by dry persistent leaves and sheaths. *Tillering* 10, maximum obtained 26. *Canes* slightly curved, length 8′ to 10′, number of internodes 25 to 35, length of internodes 4″ to 5″. *Thickness*, nodes 0·7″ to 0·9″, internodes 0·6″ to 0·8″, with a difference of about 0·1″ between the nodes and the internodes. *Colour* yellow green with patches of red, black incrustations present. *Wax* scanty. *Rooting band* broad and tubercled, *aerial roots* usually confined to the lowest 6 nodes or thereabouts though occasionally roots appear high up the cane. *Dormant buds* flat and circular, provided with two wing-like scales, sprouting from the top. *Colour band* distinct yellow brown or greenish. *Leaves* bent over, medium, size of blade 3′ 6″ by 1·7″, colour light green, *ligular band* reddish. Weight of 100 canes 164 lbs.

This cane is hardly distinguishable from *Maneria*. It flowered at Sabour in 1911, the flowers being similar to those of *Maneria* and *Khari*, the anthers did not open. Like *Maneria* it is very liable to red rot and white borer.

19. LATA.—*Clumps* tall and spreading or bending over, canes indifferently covered with dry persistent leaves and sheaths. *Tillering* 11, maximum obtained 23. *Canes* somewhat curved, length 8′ to 10′, number of internodes 25—35, length of internodes 4″—5″. *Thickness*, nodes 0·7″ to 0·9″, internodes 0·6″ to 0·8″, with a difference of about 0·1″ between the nodes and the internodes. *Colour* yellow green with patches of red, black incrustation present. *Wax* scanty. *Rooting band* broad and tubercled, *aerial roots* usually confined to the lowest 6 nodes though occasionally found high up the cane. *Dormant buds* flat and circular, sprouting from the top. *Colour band* present, brownish or greenish. *Leaves* medium, bent over, size of blade 3′ by 1·5″ or more, colour light green, *ligular band* reddish. Weight of 100 canes 144 lbs.

This cane is hardly distinguishable from *Maneria*, but if anything, is more spreading in its habit. It has not been found in flower at Sabour nor has been reported to have flowered anywhere

else in the Province. It is very liable to attacks of red rot and white borer.

20. KHAGRI.—*Clumps* tall and spreading, canes indifferently covered by dry persistent leaves and sheaths. *Tillering* 12. *Canes* somewhat curved, length 8′ to 10′, number of internodes 25—35; length of internodes 4″—5″. *Thickness*, nodes 0·7″ to 0·9″, internodes 0·6″ to 0·8″, with a difference of about 0·1″ between the nodes and the internodes. *Colour* yellow green with patches of red, black incrustations present. *Wax* scanty. *Rooting band* broad, *aerial roots* usually confined to the lowest 6 nodes, occasionally rooting high. *Dormant buds* flat and circular, sprouting from the top. *Colour band* present, brownish or greenish. *Leaves* medium, bent over, size of blade 3′ by 1·6″, colour light green, *ligular band* reddish. Weight of 100 canes 137 lbs.

This cane is very similar to *Maneria*. It has not flowered at Sabour or anywhere else in the Province that we know of. It is very liable to red rot and white borer.

21. KETARI No. III.—*Clumps* tall and spreading, canes indifferently covered by dry persistent leaves and sheaths. *Tillering* 9, maximum obtained 18. *Canes* slightly curved; length 8′-10′, number of internodes 25—35, length of internodes 4″ to 5″. *Thickness*, nodes 0·7″ to 0·9″, internodes 0·6″ to 0·8″, with a difference of about 0·1″ between the nodes and the internodes. *Colour* yellow green with patches of red, black incrustations present. *Wax* scanty. *Rooting band* broad and tubercled, *aerial roots* usually confined to the lowest 6 nodes, but occasionally present at the higher nodes. *Dormant buds* flat, sprouting from the top. *Colour band* present, brownish or greenish. *Leaves* medium, bent over, size of blade 3′ by 1·7″, colour light green, *ligular band* reddish. Weight of 100 canes 144 lbs.

This cane is hardly distinguishable from *Maneria*. It has not flowered at Sabour and has not been reported to have flowered anywhere else in the Province. It is very liable to attacks of red rot and white borer.

22. Chynia No. II.—*Clumps* tall and spreading, canes covered indifferently with dry persistent leaves and sheaths. *Tillering* 13·5. *Canes* more or less straight, length 7′—9′, number of internodes 25—35, length of internodes about 4″. *Thickness*, nodes 0·7″ to 0·8″, internodes 0·6″ to 0·7″, with a difference of about 0·1″ between the nodes and the internodes. *Colour* yellow green, with red patches and black incrustations. *Wax* scanty. *Rooting band* broad and tubercled, *aerial roots* usually confined to about 6 lowest nodes, but sometimes rooting high. *Dormant buds* flat. *Colour band* present, brownish or greenish. *Leaves* medium, bent over, size of blade 3′ by 1·7″, colour light green, *ligular band* reddish. Weight of 100 canes not available.

This cane is similar to *Maneria* and is very liable to red rot and white borer. It has not flowered at Sabour.

23. Khelia.—*Clumps* spreading or laid on the ground, rarely standing up, canes indifferently covered by dry persistent leaves and sheaths. *Tillering* 8, maximum observed 16. *Canes* very much curved, length 8′ to 10′, number of internodes 25 to 30, length of internodes 5″ to 6″. *Thickness*, nodes 0·8″ to 1″, internodes 0·6″ to 0·8″, with a difference of more than 0·1″ between the nodes and the internodes. *Colour* varies from red to reddish yellow, where covered by sheaths, black incrustations present here and there. *Wax* present all over the cane but more thickly at wax band. *Rooting band* well marked, broad and tubercled; *aerial roots* usually confined to the lowest 6 nodes. *Dormant buds* longer than broad, flat and tapering, usually situated in sunken groves, sprouting rarely from the top of the cane where laid. *Colour band* yellowish or reddish. *Leaves* medium to broad, bent over at the top, size of blade about 3′ 6″ by 2″, colour light green, *ligular band* brownish with faintly reddish edges. Weight of 100 canes 168 lbs.

This cane is very different from the canes previously described. It flowered at Sabour in 1911, when the anthers dehisced. It is not very liable to red rot or white borer.

24. STRIPED BANSA.—*Clumps* tall and upright, or slightly spreading, canes very indifferently covered by loosely persistent dry leaves and sheaths. *Tillering* 7, maximum observed 10. *Canes* tall and more or less straight, internodes slightly zig-zag, *length* 7′ to 8′, number of internodes 25 to 35, length of internodes $3\frac{1}{2}''$ to $4\frac{1}{2}''$. *Thickness*, nodes 0·7″ to 0·9″, internodes 0·65″ to 0·85″, with a difference of less than 0·1″ between the nodes and the internodes. *Colour* striped yellow and red, black incrustations occasionally present. *Wax* scanty except at the depressed wax band. *Rooting band* narrow and almost inconspicuous; *aerial roots* confined to the lowest 6 nodes. *Dormant buds* variable in shape, generally long and tapering and provided with two wing-like scales, sprouting from the top common. *Colour band* deeper reddish than the surrounding region. *Leaves* medium, straight with a bend at the top, size of blade 3′ by 1·5″, colour light green, *ligular band* brownish. Weight of 100 canes 164 lbs.

This cane differs from the above and all other canes in many important points. It is not very liable to red rot but white borer is frequently found to attack it. It has not flowered at Sabour and is not reported to have flowered anywhere else in the Province.

25. KAJLA.—*Clumps* tall or rather of medium height and spreading, canes loosely covered by dry persistent leaves and sheaths. *Tillering* 6, maximum observed 14. *Canes* slightly curved, length 7′ to 8′, number of internodes 25 to 35, length of internodes 4″ to 5″. *Thickness*, nodes 0·9″ to 1″, internodes 0·9″ to 1″, and top of internode slightly less than the middle, the narrowest part being the wax band which forms a depressed ring. *Colour* varies from light red to deep purple. *Wax* present thinly all over the cane and very thickly in the wax band. *Rooting band* frequently yellow and conspicuous, or red and inconspicuous. *Aerial roots* usually confined to the lowest 3 or 4 nodes. *Dormant buds* well developed and prominent, sprouting rare. *Colour band* deeper than the surrounding region. *Leaves* large and spreading, size of blade about 4′ by 2″, *colour* light green, *ligular band* dark brownish. Weight of 100 canes 226 lbs.

This cane is not very liable to attacks of red rot, but white borer is frequently found to attack it. It has not flowered at Sabour and has not been reported to have flowered anywhere else in the Province. The shape of the cane indicates that it may be a degenerated Mauritius cane.

26. RED MAURITIUS.—*Clumps* tall, upright or slightly spreading. Canes exposed in many parts. *Tillering* 5. *Canes* more or less straight, length 7½′ to 8½′, number of internodes 20 to 30, length of internodes 4″ to 5″. *Thickness*, nodes 0·9″ to 1·2″, internodes 0·7″ to 1·2″, top of internodes about the same as the middle or slightly less, the narrowest part being the depressed wax band. *Colour* varies from light red to purple. *Wax* thin coat present all over the canes, thick at the wax band. *Rooting band* narrow and either of the same colour as the cane or yellow where the cane is covered by sheaths. *Aerial roots* usually confined to the lowest 3 or 4 nodes. *Dormant buds* slightly tapering, sprouting rare. *Colour band* almost invisible. *Leaves* large and spreading, size of blade about 4′ by 2″, colour light green, *ligular band* reddish brown. Weight of 100 canes 287 lbs.

This cane is somewhat similar to *Kajla* though distinguishable from it. It has not flowered nor has been reported to have flowered. It is not very liable to red rot, though white borer is occasionally found to attack it.

27. BOMBAY.—*Clumps* tall or of medium height, spreading, canes mostly exposed. *Tillering* 5, maximum obtained 11. *Canes* straight or slightly curved, length 6′ to 7′, number of internodes 25—30, length of internodes 4″ to 4½″. *Thickness*, nodes 1·1″ to 1·3″, internodes 1·1″ to 1·5″, top of internodes 1·1″ to 1·3″, hence the internodes are sometimes barrel shaped. *Colour* light red to chocolate. *Wax* present all over the cane, more thickly below nodes in wax bands. *Rooting band* inconspicuous or yellow where covered by the sheaths. *Aerial roots* usually confined to the lowest 3 or 4 nodes. *Dormant buds* tapering, sprouting almost absent. *Colour band* inconspicuous. *Leaves* large and spreading,

size of blade 4′ 6″ by 2·5″, colour light green, *ligular band* brownish. Weight of 100 canes 348 lbs.

A rather soft and good chewing cane, very liable to red rot, but almost free from the attacks of white borer. It has not flowered at Sabour.

28. RED BOMBAY.—*Clumps* tall or of medium height, spreading, canes mostly exposed. *Tillering* 5, maximum obtained 10. *Canes* straight or slightly curved, length 6′ to 7′, number of internodes 25—30, length of internodes 4″ to 4½″. *Thickness*, nodes 1″ to 1·3″, internodes 1·1″ to 1·5″ and top of internodes about the same as nodes, hence the internodes are sometimes barrel shaped. *Colour* light red to chocolate. *Wax* present all over the cane, more thickly in wax band. *Rooting band* sometimes yellow and conspicuous where covered by the sheath, *aerial roots* usually confined to the lowest 3 or 4 nodes. *Dormant buds* tapering, sprouting rare. *Colour band* inconspicuous. *Leaves* large and spreading, size of blade 4½′ by 2·5″, colour light green, *ligular band* brownish. Weight of 100 canes 287 lbs.

This cane is exactly similar to Bombay, and is probably the same cane, with a different name. It is a soft and good chewing cane, rather liable to attacks of red rot, but free from white borer. It has not flowered at Sabour.

29. BHURI.—*Clumps* tall or of medium height, spreading, canes mostly exposed. *Tillering* 6, maximum obtained 12. *Canes* straight or slightly curved, length 6′ to 7′, number of internodes 20—25, length of internodes 4½″ to 5″. *Thickness*, nodes 1″ to 1·2″, internodes 1″ to 1·3″, top of internodes 1″ to 1·2″, hence the internodes are slightly barrel shaped. *Colour* light red to chocolate. *Wax* present all over the cane, more thickly in wax band. *Rooting band* inconspicuous where exposed, yellow where covered by sheath. *Aerial roots* usually confined to the lowest 3 or 4 nodes. *Dormant buds* tapering, sprouting rare. *Colour band* inconspicuous. *Leaves* large and spreading, size of blade 4′ 6″ by 2·5″, colour light green, *ligular band* brownish. Weight of 100 canes 287 lbs.

This cane is exactly similar to Bombay and Red Bombay, and is probably the same cane with a different name. It is a soft and good chewing cane like the above, but is very liable to attacks of red rot, though comparatively free from the attacks of white borer. It has not flowered at Sabour.

30. Red Java.—*Clumps* tall and typically upright, canes mostly exposed. *Tillering* 4, maximum observed 9. *Canes* typically straight, length 7′ to 8′, number of internodes 20—30, length of internodes $4\frac{1}{2}''$ to $5\frac{1}{2}''$. *Thickness*, nodes 1·1″ to 1·5″, internodes 1″ to 1·3″, with little or no difference between nodes and internodes. *Colour* yellow green with a tinge of red, when fully ripe somewhat brownish with longitudinal streaks. *Wax* almost absent in the mature internodes but thickly present in the wax band. *Rooting band* often well marked. *Aerial roots* usually confined to the 3 or 4 lowest nodes. *Dormant buds* very small and hemispherical, sprouting absent. *Colour band* narrow and deeper coloured than the surrounding region. *Leaves* large and spreading, *size of blade* 5′ by 2·5″, colour light green, *ligular band* brownish. Weight of 100 canes 350 lbs.

A thick but very hard cane often becoming pithy in the centre, hence not a good chewing cane. It is not very liable to red rot and is free from the attacks of white borer. It has not flowered at Sabour.

31. Red Tanna.—*Clumps* tall and typically upright, canes mostly exposed. *Tillering* 5. *Canes* typically straight, length 7′ to 8′, number of internodes 20—30, length of internodes $4\frac{1}{2}''$ to $5\frac{1}{2}''$. *Thickness*, nodes 1″ to 1·5″, internodes 1″ to 1·5″, slightly narrower at the top of the internode. *Colour* yellow green with a tinge of red, when fully ripe somewhat brownish with longitudinal streaks. *Wax* almost absent in the internodes, thickly present in the wax band. *Rooting band* often well marked. *Aerial roots* usually confined to the lowest 3 or 4 nodes. *Dormant buds* very small and hemispherical, sprouting absent. *Colour band* narrow and deeper coloured than the surrounding region. *Leaves* large

and spreading, *size of blade* 5′ by 2·5″, colour light green, *ligular band* brownish. Weight of 100 canes 370 lbs.

This cane is exactly similar to Red Java and is probably the same cane with a different name.

32. WHITE MAURITIUS.—*Clumps* tall and upright or slightly spreading, canes mostly exposed. *Tillering* 5, maximum obtained 10. *Canes* straight or slightly curved, length 7′ to 8′, number of internodes 25 to 30, length of internodes 4″ to 5″. *Thickness*, nodes 0·9″ to 1·1″, internodes 0·9″ to 1·1″, with little or no difference between the nodes and the internodes. *Colour* greenish yellow. *Wax*, thin coat present all over the cane, thick deposit at the depressed wax band. *Rooting band* inconspicuous. *Aerial roots* usually confined to the lowest 3 or 4 nodes. *Dormant buds* flat and pointed, provided with two wing-like scales, sprouting rare. *Leaves* large and spreading, size of blade 4′ by 2″, colour light green, *ligular band* brownish. Weight of 100 canes 287 lbs.

This cane has not flowered at Sabour. It is not very liable to attacks of red rot or white borer.

33. DHALSUNDER.—*Clumps* tall and spreading, canes mostly exposed. *Tillering* 6, maximum obtained 11. *Canes* straight or slightly curved, length 7′ to 9′, number of internodes 25 to 35, length of internodes 4″ to 5″. *Thickness*, nodes 0·9″ to 1·5″, internodes 0·9″ to 1·3″, with a slight difference in thickness between the nodes and internodes. *Colour* yellow green with tinge of red, ripe canes brownish. *Wax* almost absent except at the wax band. *Rooting band* inconspicuous. *Aerial roots* usually confined to the lowest 3 or 4 nodes, occasionally higher up. *Dormant buds* long and tapering, situated in grooves, sprouting rare. *Colour band* deeper than the surrounding region. *Leaves* large and spreading, size of blade 4′ by 2½″, colour light green, *ligular band* brownish. Weight of 100 canes 287 lbs.

A good soft chewing cane though occasionally liable to become pithy in the centre. Not very liable to attacks of fungus or insect. It has not flowered at Sabour.

34. Benaresia-Nepali.—*Clumps* medium or short, slightly spreading or upright, canes indifferently covered by dry persistent leaves and sheaths. *Tillering* 6, maximum obtained 15. *Canes* almost straight or slightly curved, length 5′ to 6′, number of internodes 20 to 25, length of internodes $3\frac{1}{2}''$ to $4\frac{1}{2}''$. *Thickness,* nodes 0·9″ to 1·3″, internodes 0·9″ to 1·3″, with slight difference in thickness between nodes and internodes. *Colour* yellow and green in which the green predominates, sometimes a tinge of red is also present. *Wax* very scanty except at the wax band. *Rooting band* inconspicuous. *Aerial roots* usually confined to the few lowest nodes, occasionally rooting very high. *Dormant buds* tapering, sprouting rare. *Colour band* deeper than the surrounding region. *Leaves* large and spreading, size of blade $4\frac{1}{2}'$ by $2\frac{1}{2}''$, colour light green, *ligular band* yellowish. Weight of 100 canes 246 lbs.

A good chewing cane usually free from red rot and white borer. It has not flowered at Sabour.

35. Shamshara.—*Clumps* short or medium, upright or slightly spreading, canes indifferently covered by dry leaves and sheaths. *Tillering* 5, maximum obtained 7. *Canes* more or less straight, length 5′ to 6′, number of internodes 20—25, length of internodes 3″ to 4″. *Thickness,* nodes 0·9″ to 1·1″, internodes 0·9″ to 1·1″, with little or no difference in thickness between the nodes and internodes. *Colour* yellow and green in which the green predominates, sometimes a tinge of red is also present. *Wax* very scanty except at the wax band. *Rooting band* inconspicuous. *Aerial roots* usually confined to the few lowest nodes, occasionally roots are developed high up the cane. *Dormant buds* tapering, sprouting rare. *Colour band* deeper than the surrounding region but not well defined. *Leaves* large and spreading, size of blade 4′ 6″ by 2·5″, colour light green, *ligular band* yellowish. Weight of 100 canes 205 lbs.

This cane appears very similar to *Benaresia-Nepali* and is probably the same cane with a different name. It does not seem to be doing well at Sabour though it is a famous cane of Bengal. It is a good chewing cane and is generally free from the attacks of red rot or white borer. It has not flowered at Sabour.

36. SUKLI.—The cane has considerably deteriorated since introduced at Sabour and the observations of the last 2 or 3 years are useless and misleading. Hence the observations of 1911 are given below :—*Clumps* tall, straight up or slightly spreading, canes indifferently covered by dry persistent leaves and sheaths. *Tillering* 8, maximum obtained 15. *Canes* more or less straight, length 7′ to 8′, number of internodes 25 to 35, length of internodes about 4″. *Thickness*, nodes 0·9″ to 1·1″, internodes 0·9″ to 1·1″, with constriction at the wax band. *Colour* lemon yellow and green. *Wax* scanty except at wax band. *Rooting band* inconspicuous. *Aerial roots* high up the cane. *Dormant buds* small. *Colour band* narrow but indistinct. *Leaves* large and spreading, size of blade 4′ by 2·5″, colour light green, *ligular band* yellowish. Weight of 100 canes 230 lbs.

A very good and soft chewing cane when growing to perfection, but very liable to red rot. It has not flowered at Sabour.

37. PURI.—Like *Sukli* this cane has also much deteriorated since introduced at Sabour and the observations of the last 2 or 3 years are misleading, hence the observations of 1911 are given below. *Clumps* medium and slightly spreading, canes indifferently covered by dry persistent leaves and sheaths. *Tillering* 8, maximum observed 21. *Cane* more or less straight. *Length* 6′ to 7′, number of internodes 25 to 30. Length of internodes about 3″. *Thickness*, nodes 0·9″ to 1·1″, internodes 0·9″ to 1·1″, with a constriction at the wax band. *Colour* green to amber yellow. *Wax* almost absent except at wax band. *Rooting band* inconspicuous. *Aerial roots* high up the cane to nearly two-thirds of the cane. *Dormant buds* tapering. *Colour band* indistinct. *Leaves* large and spreading, size of blade 4′ 6″ by 2″, colour light green, *ligular band* yellowish brown. Weight of 100 canes 165 lbs.

IV.—Classification of varieties.

With the above descriptions of the varieties before us we are now in a position to come to some conclusion regarding their relationships.

A.—Shorter bushy canes.

Group 1.—A study of the first seven varieties *Buxaria, Hemja, Mango, Lewari, Rheora, Paunri* and *Poraya* shows that they are very similar and may be grouped together as short bushy canes with the following common characters.

Clumps short, erect or slightly spreading, canes completely covered by dry persistent leaves and sheaths. *Tillering* comparatively high, between 10 to 16. *Canes* more or less straight. Length 5′—6′, number of internodes about 30, length of internodes about 3″. *Thickness* varies from 0·6″ to 1″ with no difference between nodes and internodes. *Colour* honey yellow to sea green in varying proportion. *Wax* thickly present all over the cane, more thickly at the wax band. *Rooting band* inconspicuous. *Aerial roots* typically absent. *Dormant buds* stout and conical, sprouting common where attacked by white borer. *Colour band* absent. *Leaves* narrow with a bend at the tip. The arrangement of the leaves at the crown is shown in Fig. 1, Plate III, size of blade 3′ to 3′—6″ by 1″—1·5″; colour light green, *ligular band* yellowish green. Weight of 100 canes varies according to the size and thickness. Not given to flowering nor liable to attacks of red rot.

The canes differ somewhat from each other in these respects, but it cannot be said that they could always be distinguished by these characters even when grown and examined side by side. *Buxaria, Hemja* and *Poraya* are slightly thicker and have a lower tillering capacity than the other members of the group, *Paunri* being intermediate. As regards leaf characters *Buxaria* and *Poraya* have broader leaves than the rest. *Poraya* is taller and more

spreading than *Buxaria*. *Lewari* and *Mango* are very similar and are shorter than *Paunri* and *Rheora*, which last cane has the highest tillering capacity of the group.

Group 2.—*Shakarchynia* occupies an intermediate position between the above canes and the canes which follow, namely, *Bansa* and *Ketari No. I*. It agrees with the short bushy canes in the appearance of the clumps, in high tillering, in the appearance, length and thickness of the canes and in the colour of the cane, but it differs from them in many important points. The average internodes are longer than in the above group, being nearly 3·5″, wax is scanty except at the wax band, aerial roots are developed in the lower nodes, and sometimes also in the higher nodes, a distinct though narrow colour band is present, the leaves are typically straight and arranged in a fan-like manner and they are also shorter. It will be presently seen that in the presence of aerial roots and the colour band it agrees with the *Bansa* type though the leaf arrangement is peculiar to itself. It should also be noted that this cane is given to flowering.

B.—Tall canes.

Next to *Shakarchynia* we have a large number of canes which are comparatively tall and may be grouped under *Tall canes*. They include canes numbered 9 to 22. By a comparative examination of these canes it is possible to sub-divide them into four distinct groups, three of which have been represented in Plate II.

Group 3.—The first of these groups includes canes numbered 9 and 10, namely, *Bansa* and *Ketari No. I* with the following characters :—Their bushes are seldom upright, but mostly spreading or laid on the ground, canes usually unevenly covered with dry persistent leaves and sheaths ; tillering lower than the 1st group ; internodes longer than in the first group, being 3″ to 4″, and differing from *Shakarchynia* in having their nodes thicker than the internodes, except for the black incrustations colour bright yellow green as in *Shakarchynia* and wax as thick as in the first group ; rooting band and internodes with peculiar brown streaks. Aerial roots and

colour bands developed but the rooting usually confined to the lowest six nodes; leaves more or less upright and arranged in the manner shown in Plate III, Fig. 1, ligular band faintly reddish yellow, the red being often in the border.

The two canes in this group differed slightly in length and thickness in 1913, but in their other characters they would appear to be of one type.

Group 4.—The next group of tall canes include *Baraukha, Kewali, Nargori, Ketari No. II* and *Chynia No. I* and are distinguished by having their bushes upright or slightly spreading, in exhibiting a well marked difference in thickness between the nodes and the internodes, the thickness of which is often more than 0·1″; except in *Nargori* the colour is usually a dirty yellow green. The aerial roots are developed high up the cane. The colour band is inconspicuous. The leaves are more or less bent over. The arrangement of leaves in the crown is an advanced form of what has been represented in Plate III, Fig. 2. The canes of this group are apparently all of one type except *Nargori*, which differs from the others only in its higher tillering capacity, brighter colour and the spreading habit of its young shoots. The group agrees more or less with the previous group in tillering, in the length and thickness of canes and in the number and length of its internodes.

Group 5.—The variety *Khari* occupies a place intermediate between the *Baraukha* and *Maneria* groups. In fact except in having aerial roots well developed high up the canes it has no other point of agreement with the *Baraukha* type; and although it agrees with the *Maneria* group in certain points it still has characters of its own which separate it from the *Maneria* group. The colour band is broad and prominent and the ligular band is brownish. The cane flowers frequently and is peculiarly liable to attacks of the Smut disease.

Group 6.—The *Maneria* group is represented by *Maneria, Panshahi, Lata, Khagri, Ketari No. III* and *Chynia No. II*. They are more or less similar in appearance and it is difficult to separate

them from one another. The clumps are more spreading than the *Baraukha* group though not as prostrate as the *Bansa* group. In tillering all the tall canes seem to agree more or less. In the length and thickness of the cane the *Maneria* group appears to be superior to the others, only *Khari* approaching it in length. In the number and length of internodes we find that the average number of internodes is 25 to 35 and the average length of internodes is 4″ to 5″ as compared with 30—40 internodes and 3″ to 4″ length of internodes in *Bansa* and *Baraukha* groups. In this respect also *Khari* is similar to the *Maneria* type. The difference in thickness between nodes and internodes in the *Maneria* group is about 0·1″. The rooting band is prominent and tubercled and aerial roots are usually confined to the lowest 6 nodes thus agreeing with the *Bansa* group but differing from the *Baraukha* group and the *Khari* canes. A distinct colour band is present in this group, though not as well marked as in *Khari*. In leaf characters it agrees with the *Baraukha* group but the ligular band is reddish here as distinguished from yellowish in *Baraukha* group. The difference between the individual varieties of this group would appear to be so small as to allow of them being classed as one type.

Distinguishing characters of groups of tall canes.

For the sake of convenience the chief distinguishing characters of the various groups of tall canes are given in the following table :—

Character	*Group* 3 (Bansa.)	*Group* 4 (Baraukha.)	*Group* 5 (Khari.)	*Group* 6 (Maneria.)
Bushes	Bent over or laid on the ground.	Upright or slightly spreading.	Spreading	Spreading.
Length of internodes.	3″ to 4″	3″ to 4″	4″ to 5″	4″ to 5″
Thickness of canes.	Thinner	Thinner	Thicker	Thicker.
Colour of cane.	Light yellow green.	Dirty yellow green.	Reddish yellow green.	Yellow green.
Aerial roots	Rooting low	Rooting high	Rooting high	Rooting low.
Colour band	Narrow	Indistinct	Broad	Medium.
Leaves	More upright	More bent over	More upright	More bent over.
Ligular band	Faintly reddish yellow.	Yellowish	Brownish	Reddish.

Groups 7 and 8.—Striped *Bansa* is the only striped cane that has been grown here and *Khelia* is a tall red cane with swollen nodes, this cane is usually badly laid and is distinguished by being the only cane which has produced fertile anthers here.

C.—Miscellaneous thick canes.

The remaining canes are mostly foreign canes each with its own distinguishing characters which will be found in the descriptions. The canes have not grown sufficiently well at Sabour to enable us to be certain of their characters and so we only put forward the following suggestions. All except *Sukli* and *Puri* have large light yellow leaves. The varieties Bombay, Red Bombay and *Bhuri* appear to be the same cane with different names. Similarly Red Java and Red Tanna are also probably the same cane with two different names. *Benaresia-Nepali* and *Shamshara* seem to be closely allied canes and were probably originally the same cane. *Khajla* may be a degenerated form of Red Mauritius, with which it agrees in the barrel-like shape of the cane. It differs, however, from Mauritius in having a more spreading habit, more persistent leaf sheaths, deeper colour and a thicker deposit of wax. *Sukli* and *Puri* have not grown satisfactorily at Sabour and we do not venture to offer any opinion on them.

In the above paragraphs the canes have been classified generally into groups but usually no great stress has been laid on stating whether the varieties of a group are exactly of one type or not. This is due to the fact that the influence of cultivation and season affects many of the characters examined to such an extent as to make it difficult to do this, until all the varieties shall have been studied side by side in various environments.

V.—Conclusions.

The chief interest of this paper lies in the fact that it records the results of the first attempts made in India to propagate sugar-cane by the method of pure line cultures. From the information given in the Introduction it is clear that any attempts to obtain reliable results from experiments on the agricultural, botanical, or chemical characters of cane varieties must prove abortive unless pure cultures are used for the experiments.

When once the local varieties had been established in pure culture and the various types isolated it was possible to undertake accurate work on the study of their distinguishing characters, regarding which very little exact data had previously been collected. The information obtained on the subject of the distinguishing characters of the cane is dealt with in Sections II and III and Appendix II, from which it will be seen that there are a larger number of simple field characters by which cane varieties can be distinguished.

In addition to their obvious use in distinguishing cane varieties it is hoped that the detailed observations made regarding the various varieties will prove useful in studying the behaviour of these canes under different climatic and soil conditions and it will thereby be possible to obtain an idea of the suitability of the various groups of canes for the various cane tracts of India. The results of these observations should also in future provide useful information regarding the subject of deterioration.[1]

[1] It is not unlikely, however, that the degeneration of the *dhaul* cane of the United Provinces to *chamli* and *dhumar* is due rather to the admixture of these inferior types than to deterioration due to any defect in the preparation of the cuttings (*vide* Hadi's *Sugar Industry of United Provinces*, page 6).

It has unfortunately not been hitherto possible to take up the study of the chemical and agricultural characters of the cane on a sufficiently large scale to ensure results owing to the small area available for sugarcane work here. These most important branches of the work must therefore lie fallow for the present, and a complete account of the cane varieties and their products with any recommendations as to the best varieties for cultivation is at present out of the question.

SABOUR,
July 31st, 1914.

APPENDIX I.

Table showing the history of the cane varieties.

1	2	3	4	5	6	7	8	9	10
No.	Name.	Locality whence obtained.	Plot number of crop planted in spring of year :—						REMARKS.
			1909.	1910.	1911.	1912.	1913.	1914.	
1	Bangla	..	1, 2						
2	Bansa	Purulia	50	18	51	9A-D	12A	9	
				18	52	9E-F	12B	S	
3	Baraukha	Behta	13, 14	6	45	13A-D	17A	11	
				6	46	13E-I	17B	S	
4	Benarasia-Nepali.	Bankipur	21, 22	25	77	33A-C	35A	34	+S
				25	78	—	—		
5	Bombay	Calcutta	61	22	63	22A-C	27A	27	
				22	64	22D-F	27B	S	
6	Bombay Red.	Satgachia (Burdwan).	80, 81	31	65	23A-B	28A	28	
				31	66	23C-D	28B	S	
7	Bhuri	Mohisadal	72, 73	28	67	24A-B	29A	29	
				28	68	24C-D	29B	S	
8	Buxaria	Behta	7, 8	2	10	1A-B			
				2	11	1C	3A	1	
				2	12				
				4A	13	1D-E	3B	S	
				4A	14				
				4B	15				
				4B	16				
9	Chynia	Behta	4, 5	1	38				
				3	39	21A-B	26A	22	Chynia No. II
				3	40	21C	26B	S	do.
				3	41	21E-F	25A	15	do. No. I
				3	42	21G-H	25B	S	do. do.
10	Dhalsundar.	Kustia	89, 90	34	81	34A-B	36A	33	
					82	34C-D	36B	S	
11	Hemja	Saran	29, 30	10	17	2A-E	4A	2	+S
				10	18	2F-H			
				10	19				
12	Java	Burdwan Farm.			1	26A-B	31A	30	
						26C	31B	S	
13	Ketari	Behta	10, 11	5	43	12A-B	15A	10	Also 20G, H of '12 as 15B of '13 sent to Sepaya: Ketari No. I

Col. 6 :—The crop planted in 1911 is the first crop derived from single selected plants.

Col. 7 :—The plots A, B & C of each variety in 1912 were derived from single selected plants and as they were all derived from the original single selected plants in 1911 it is immaterial as to which plot was used for continuing the strain in 1913.

Col. 9 :—The letter S represents the strain sent to the Sepaya sugarcane station for field tests.

Col. 10 :—+S indicates that this strain was both planted at Sabour and sent to Sepaya.

Table showing the history of the cane varieties.—contd.

1	2	3	4	5	6	7	8	9	10
No.	Name.	Locality whence obtained.	Plot number of crop planted in spring of year :—						REMARKS.
			1909.	1910.	1911.	1912.	1913	1914.	
				5	44	12C-I	16A	14	Also 20I-J of '12 as 16B of '13 sent to Sepaya, Ketari No. II. Ketari No. III.
14	Ketari	Kanti (Muzaffarpur).	39	14	36	20A-D	24A	21	
				14	37	20E-F	24B	S	do.
15	Kewali	Behta	16, 17	7	47	14A-D	18A	12	
				7	48	14E-G	18B	S	
16	Khagri	Midnapur.	77, 78	30	62	19A-D	23A-B	20	+S
17	Khajla	Burdwan	92, 93	35	69	25A	30A	25	
			,, ,,	35	70	25B-D	30B	S	
18	Khari	Dumraon	66, 67	26	8	11D-F			
			,, ,,	26	7				
			,, ,,	26	9	11G-H	14B	S	
18	(a) Khari	Burdwan Farm.			2				
					3	11A	14A	16	
					4				
					5				
					6	11B, C			
18	(b) Khari	..	..	..	88				
19	Khelia	Kustia	63, 64	23	53	10A-C	13A	23	
				23	54	10D-F	13B	S	
20	Lata	Kustia	58, 59	21	59	18A-D	22A	19	
				21	60	18E-H	22B	S	
21	Lewari	Palmergunj.	55, 56	19	26	4A-L	7A	4	
				19	27	4M-P	7B	S	
22	Maneria	Fatua (Patna)	32, 33	11	55	16A-D	20A	17	
				11	56	16E-H	20B	S	
23	Mango	Fatua (Patna.)	35	12	20	3A, B	—	—	
				12	21	3C-D	5	3	+S
				12	22				

Col. 6 :—The crop planted in 1911 is the first crop derived from single selected plants.

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Table showing the history of the cane varieties.—contd.

1	2	3	4	5	6	7	8	9	10
No.	Name.	Locality whence obtained.	Plot number of crop planted in spring of year :—						REMARKS.
			1909.	1910.	1911.	1912.	1913.	1914.	
23	(a) Mango	Ranchi	75	29	24	3E-I	6		
				29	25	3J-L			
24	Mauritius, Red.	Sathi			86	27A-C	32	26	+S
25	Mauritius, White.	Sathi			85	30A-E	34	32	+S
26	Nargori	Kanti (Muzaffarpur).	41, 42	15	49	15A-C	19A	13	
				15	50	15D-F	19B	S	
27	Pandi	Satgachia (Burdwan).	83, 84	32	73	38A-B			
				32	74	38C-D	..		
28	Panshahi	Saran	26, 27	9	57	17A-D	21A	18	
				9	58	17E-H	21B	S	
29	Paunda	Bankipur	19, 20	24					
30	Paunri	South Bhagalpur.	44, 45	16	30	6A-E	9A	6	
				16	31	6F-H	9B	S	
31	Poraya	Dumraon	47, 48	17	32	7A-E	10A	7	
				17	33	7F-G	10B	S	
32	Puri	Oaryia (Burdwan).	86, 87	33	71	37A-B	39A	37	
				33	72	37C-D	39B	S	
33	Rheora	Saran	23, 24	8	28	5A-C	8A	5	
				8	29	5A-G	8B	S	
34	Shakarchynia.	Fatua (Patna).	37	13	34	8A-D	11A	8	
				13	35	8E-H	11B	S	
35	Shamshara	Calcutta	52, 53	20	79	35A-B	37A	35	
				20	80	35C-E	37B	S	
36	Striped Bansa.	..	..	..	83	29A-B	33A	24	
					84	29C-D	33B	S	
37	Sukli	Burdwan	69, 70	27	75	36A-B	38A	36	
				27	76	36C-D	38B	S	
38	Tanna	Sathi	..	..	87	28A-D	40	31	+S

Col. 6 :—The crop planted in 1911 is the first crop derived from single selected plants.

Col. 7 :—The plots A, B & C of each variety in 1912 were derived from single selected plants and as they were all derived from the original single selected plants in 1911 it is immaterial as to which plot was used for continuing the strain in 1913.

Col. 9 :—The letter S represents the strain sent to the Sepaya sugarcane station for field tests.

Col. 10 :—+S indicates that this strain was both planted at Sabour and sent to Sepaya.

APPENDIX II.

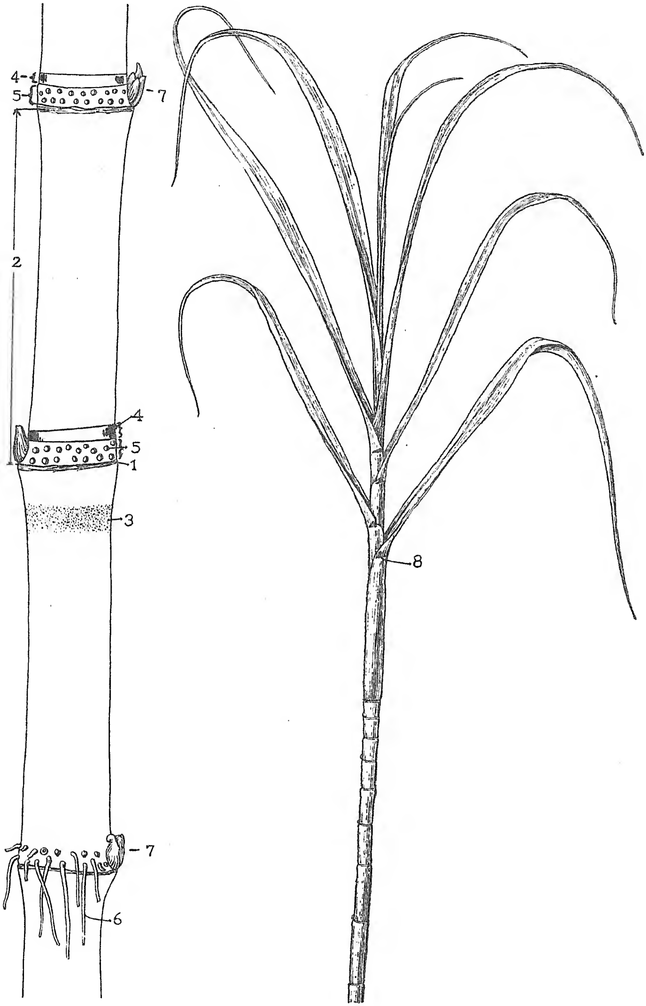
Table showing observations made in 1913.

No.	Variety of cane.	Appearance of clump.	Tillering.	Appearance of cane.	Length.	Number of internodes.	Length of internodes.	Thickness of nodes.	Thickness of middle of internodes.	Thickness of top of internodes.	Colour of cane.	Wax.	Colour band.	Aerial roots.	Buds.	Sprouting.	Appearance of leaves.	Length of leaves.	Breadth of leaves.	Colour of leaves.	Ligular band.	Weight of 100 canes.	Remarks.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
												A.—Short bushy canes.											
												Group 1.											
1	Buxaria ..	Typically straight, and canes covered with sheaths.	9	Short, straight and of medium thickness.	4′–6″	26	3″	·87″	·89″	·87″	From honey-yellow to sea-green. Red patches present.	Present all over the cane, thickly below nodes.	Not well defined.	Typically absent.	Stout and of equal length and breadth.	Generally absent.	More or less upright with a slight bend at the top, appearing in tufts.	3′–3″	1·3″	Light green ..	Yellowish ..	140 lbs.	
2	Hemja ..	Ditto.	10	Ditto.	4′–10″	31	2·8″	·88″	·84″	·84″	Ditto.	Ditto.	Ditto.	Ditto.	Ditto.	Profuse from the top.	Ditto.	3′–7″	1″	Ditto ..	Ditto ..	139 „	Distinguishable from the above by the narrower leaves.
3	Mango (Patna)..	Ditto.	13	Ditto.	4′–7″	27	3″	·80″	·81″	·79″	Ditto.	Ditto.	Ditto.	Ditto.	Ditto.	Less than above.	Ditto.	3′–5″	1″	Ditto ..	Ditto ..	93 „	
3a	Mango (Ranchi)	Ditto.	14	Ditto, but thinner	5′–0″	29	2·7″	·68″	·68″	·67″	Ditto.	Ditto.	Ditto.	Ditto.	Ditto.	Ditto.	Ditto.	3′–5″	1″	Ditto ..	Ditto ..	84 „	
4	Lewari ..	Ditto.	15	Ditto. ditto.	4′–8″	26	2·8″	·67″	·65″	·65″	Ditto.	Ditto.	Ditto.	Ditto.	Ditto.	Freely from the upper part of the cane.	Ditto.	3′–3″	0·9″	Ditto ..	Ditto ..	70 „	
5	Rheora ..	Ditto slightly spreading	16·5	Ditto and taller ..	5′–8″	28	3″	·73″	·72″	·70″	Ditto.	Ditto.	Ditto.	Ditto.	Ditto.	Ditto.	Ditto.	3′–2″	1″	Ditto ..	Ditto ..	102 „	
6	Paunri ..	Ditto.	12	Similar to Buxaria but taller.	5′–5″	29	3″	·82″	·83″	·79″	Ditto.	Ditto.	Ditto.	Ditto.	Ditto.	Ditto.	Ditto.	3′–3″	1″	Ditto ..	Ditto ..	114 „	
7	Poraya ..	Ditto.	10	Ditto, but taller ..	6′–0″	29	3·2″	·86″	·83″	·82″	Ditto.	Ditto.	Ditto.	Ditto.	Ditto.	Ditto.	Ditto.	3′–6″	1·2″	Darker than above	Ditto ..	168 „	
												Group 2.											
8	Shakarchynia ..	Erect or slightly spreading, s cane covered with sheaths.	14	Short, straight and thin	6′–1″	28	3·3″	·62″	·60″	·60″	Yellow-green, more yellowish.	More thinly present than the above.	A narrow yellow ring present.	Present in the lowest 6 nodes or some times higher up.	Flat and circular	Rare .	Short, narrow, typically straight and spreading like a fan.	2′–6″	0·9″	Light green ..	Yellowish ..	84 „	The canes have a tendency to crack lengthwise in the internodes.
												B.—Tall canes.											
												Group 3.											
9	Bansa ..	Bending or falling over the ground, sheaths persistent.	8·5	More or less straight, bending at the top.	8′–10″	33	3·5″	·79″	·70″	·70″	Yellow-green, more yellowish.	More thickly present than Shakarchynia.	Narrow, distinct and yellow.	Usually present in the lowest 6 nodes.	Flat with a pair of wing-like scales.	Present .	Short, narrow, and straight, making a smaller angle with the axis than Shakarchynia.	2′–10″	1·4″	Light green ..	Faintly reddish yellow.	145 „	The canes have brown streaks in the nodes and internodes.
10	Ketari No. I ..	Erect or ditto ..	8	Ditto.	6′–10″	30	3·3″	·73″	·64″	·64″	Ditto.	Ditto.	Ditto.	Ditto.	Ditto.	Ditto .	Ditto.	2′–3″	1·3″	Ditto ..	Ditto.	102 „	Ditto.
												Group 4.											
11	Baraukha ..	Tall, straight or slightly spreading, canes loosely covered with sheaths.	10	More or less straight, bending at the top.	8′–0″	32	3·5″	·76″	·64″	·62″	Dirty-yellow green	Thinly present often blackened in many places.	Present but often indistinct.	Usually present over half the length of the cane.	Flatly placed in slight groove.	Slightly	Seems to rise from different levels. Outer ones bent over, inner ones straight up.	2′–8″	1·3″	Greener than above	Yellowish ..	106 „	
12	Kewali ..	Ditto.	9	Ditto.	7′–0″	30	3·3″	·70″	·58″	·58″	Ditto.	Ditto.	Ditto.	Ditto.	Ditto.	Vigorous	Ditto.	2′–10″	1·3″	Green with a reddish wash on some leaves.	Ditto ..	106 „	
13	Nargori ..	Ditto.	13·5	Ditto.	7′–10″	34	3·4″	·70″	·58″	·57″	Ditto, slightly brighter.	Ditto.	Ditto.	Ditto.	Ditto.	Ditto	Ditto.	2′–8″	1·3″	Ditto.	Ditto ..	104 „	
14	Ketari No. II .	Ditto.	8	Ditto.	7′–8″	31	3·5″	·76″	·63″	·62″	Similar to Baraukha	Ditto.	Ditto.	Ditto.	Ditto.	Slightly	Ditto.	2′–9″	1·4″	Green with red border at the base.	Ditto ..	106 „	
15	Chynia No. I .	Ditto.	9	Ditto.	7′–8″	33	3·3″	·73″	·62″	·64″	Ditto.	Ditto.	Ditto.	Ditto.	Ditto.	Ditto	Ditto.	2′–9″	1·4″	Ditto.	Ditto ..	90 „	
												Group 5.											
16	Khari ..	Tall, erect or spreading, canes exposed in many places.	8	More or less straight ..	7′–6″	26	4·8″	·78″	·75″	·70″	A mixture of yellow-green and red.	Present ..	Broad and very distinct.	Usually present up to ¾ the length of the cane.	Flat, small in grooves.	Few	Upright ..	3′–6″	1·2″	Light green with red spots.	Yellow-greenish or brownish.	123 „	The cane is given to flowering and is very liable to Smut disease.
												Group 6.											
17	Maneria ..	Tall, spreading sheaths loosely persistent.	10	Not perfectly straight	8′–6″	28	4·5″	·80″	·72″	·70″	Yellow-green ..	Thinly present blackened in many places.	Present often very distinct.	Usually present in the lowest 6 nodes.	Flat, broader than long.	Present	Spreading and bending over.	3′–2″	1·7″	Light green with red spots.	Reddish ..	156 „	Liable to attacks of red rot.
18	Panshahi ..	Ditto.	10	Ditto.	9′–6″	30	4·6″	·79″	·69″	·69″	Ditto ..	Ditto.	Ditto.	Ditto.	Flat ..	Ditto .	Ditto.	3′–3″	1·7″	Ditto.	Ditto ..	164 „	Ditto.

Table showing observations made in **1913.—(contd.)**

No.	Variety of cane.	Appearance of clump.	Tillering.	Appearance of cane.	Length.	Number of internodes.	Length of internodes.	Thickness of nodes.	Thickness of middle of internodes.	Thickness of top of internodes.	Colour of cane.	Wax.	Colour band.	Aerial roots.	Buds.	Sprouting.	Appearance of leaves.	Length of leaves.	Breadth of leaves.	Colour of leaves.	Ligular band.	Weight of 100 canes.	Remarks.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
19	Lata ..	Tall, spreading sheaths loosely persistent but more spreading.	11	More curved than above	8′–10″	31	4·3″	0·75″	·67″	0·66″	Yellow-green ..	Thinly present, blackened in many places.	Present, often very distinct.	Usually present in the lowest 6 nodes.	Flat ..	Present ..	Spreading and bending over.	2′–7″	1·5″	Light green with red spots.	Reddish ..	144 lbs.	Liable to attacks of red rot.
20	Khagri ..	Similar to Maneria ..	..	Similar to Maneria ..	7′–11″	28	4·3″	0·83″	·72″	0·71″	Ditto ..	Ditto.	Ditto.	Ditto.	Flat and tapering	Ditto ..	Ditto.	2′–9″	1·6″	Ditto ..	Ditto ..	....	Ditto, sufficient canes were not available to take the tillering and the weight.
21	Ketari No. III ..	Ditto ..	9	Ditto ..	8′–1″	27	4·1″	0·80″	·72″	0·71″	Ditto ..	Ditto.	Ditto.	Ditto.	Ditto ..	Ditto ..	Ditto.	2′–8″	1·7″	Ditto ..	Ditto ..	144 „	Liable to attacks of red rot.
22	Chynia No. II ..	Ditto ..	..	Ditto ..	..	..	..	..	..	..	Ditto ..	Ditto.	Ditto.	Ditto.	....	Ditto ..	Ditto.	..	..	....	....	....	The general appearance of this cane is like Maneria, sufficient good canes were not available to take detailed observations.
												Group 7.											
23	Striped Bansa ..	Tall and straight with sheaths fallen off in many places.	7	Straight with a curve at the top.	6′–11″	30	4·0″	0·81″	·76″	0·77″	Striped-yellow and red.	Scanty excepting below nodes.	..	Usually confined to the lowest 6 nodes.	Flat and circular.	Very little ..	Almost upright ..	2′–9″	1·4″	Light green ..	Reddish yellow.	164 „	
												Group 8.											
24	Khelia ..	Much laid on the ground, sheaths loosely persistent.	8	Very much curved ..	8′–6″	28	4·8″	0·83″	·71″	0·73″	Reddish ..	Present, blackened in places.	..	Usually confined to the lowest 6 nodes.	Much longer than broad, generally situated in long grooves.	Present ..	More or less upright	3′–6″	1·7″	Light green with red spots.	Yellowish ..	168 „	
												C.—Miscellaneous Thick Canes.											
												(*a*) Cane-reddish.											
25	Kajla ..	Tall, erect and somewhat spreading, canes loosely covered by sheaths or exposed.	6	Not strictly straight ..	7′–6″	27	4·5″	0·95″	·95″	0·87″	Deep purple ..	White wax present all over the cane, sometimes blackened.	Deeper than the surrounding region.	Usually confined to 3 or 4 lowest nodes.	Prominent and about to sprout.	Absent ..	Large, spreading or bending over, appearing in tufts.	3′–9″	1·8″	Yellow-green ..	Brownish ..	226 „	Cane liable to crack; bloom bands constricted.
26	Red Mauritius ..	Ditto.	5	Ditto ..	7′–4″	25	4·3″	1·04″	1·07″	0·98″	Lighter than Kajla	Not so thick as Kajla	Ditto.	Ditto.	Circular, placed in grooves.	Ditto ..	Ditto.	3′–8″	2·0″	Ditto ..	Ditto ..	287 „	
27	Bombay ..	Ditto.	5	Ditto ..	6′–5″	25	4·0″	1·16″	1·28″	1·20″	Red with yellow rooting band where covered by sheaths.	Almost as thick as in Kajla.	Ditto, but not well defined.	Ditto.	Flat and conical in grooves.	Ditto ..	Ditto.	4′–4″	2·2″	Ditto ..	Ditto ..	348 „	Very liable to attacks of red rot, pig, and jackal.
28	Red Bombay ..	Ditto.	5	Ditto ..	6′–7″	24	4·4″	1·03″	1·13″	1·03″	Ditto.	Ditto.	Ditto.	Ditto.	Ditto.	Ditto ..	Ditto.	4′–4″	2·0″	Ditto ..	Ditto ..	287 „	Very liable to attacks of red rot, pig, and jackal. Same as Bombay.
29	Bhuri ..	Ditto.	6	Ditto ..	6′–8″	22	4·8″	1·07″	1·17″	1·08″	Ditto.	Ditto.	Ditto.	Ditto.	Ditto.	Ditto ..	Ditto.	4′–4″	2·0″	Ditto ..	Ditto ..	287 „	Very liable to attacks of red rot, pig, and jackal. Same as Bombay.
												(*b*) Cane-greenish.											
30	Java ..	Tall and typically erect, canes mostly exposed.	4	Tall, thick and almost upright.	7′–7″	23	4·9″	1·21″	1·14″	1·13″	Yellow-green with a wash of red in places becoming brown at maturity.	Almost absent except at the wax band.	Deeper than the surrounding region.	Usually confined to the 3 or 4 lowest nodes.	Very small and hemispherical.	Absent ..	Large, spreading or bending over, appearing in tufts.	4′–6″	2·1″	Yellow-green ..	Brownish ..	350 „	
31	Tanna ..	Ditto.	5	Ditto.	7′–4″	23	4·7″	1·26″	1·22″	1·20″	Ditto.	Ditto.	Ditto.	Ditto.	Ditto.	Ditto ..	Ditto.	4′–6″	2·3″	Ditto ..	Ditto ..	370 „	Seems to be same as Java.
32	White Mauritius	Tall and slightly spreading, canes mostly exposed.	6	Not strictly straight ..	7′–7″	27	4·4″	1·01″	1·07″	1·01″	Greenish-yellow ..	Present to about the same extent as in red Mauritius.	Ditto.	Ditto.	Flat, circular, with two wing likescales.	Ditto ..	Ditto.	3′–11″	1·7″	Ditto ..	Yellowish with very little brown.	287 „	
33	Dhalsundar ..	Tall and more spreading than above, canes mostly exposed.	5·5	Ditto ..	7′–9″	29	4·0″	1·12″	1·04″	1·06″	Ditto with a wash of red in places becoming brown at maturity.	Almost absent except at wax band.	Ditto.	Ditto, but occasionally higher up.	Nearly twice as long as broad.	Ditto ..	Ditto.	3′–4″	2·1″	Ditto ..	Ditto.	287 „	
34	Benarasia-Nepali	Short and bushy, canes loosely covered by sheaths.	6	Short, thick, and more or less straight.	5′–7″	22	3·9″	1·12″	1·09″	1·06″	Darker green than the above, changing into brown in places.	Ditto.	Ditto, but not well defined.	Confined to few lowest nodes.	$1\frac{1}{2}$ times longer than broad in grooves.	Very few ..	Ditto.	4′–6″	2·3″	Ditto ..	Yellow green with very little brown.	246 „	
35	Shamshara ..	Ditto.	4·5	Ditto.	5′–4″	22	3·5″	1·05″	1·02″	1·00″	Ditto.	Ditto.	Ditto.	Ditto.	Ditto.	Ditto ..	Ditto.	3′–9″	2·1″	Ditto ..	Ditto.	205 „	Very similar to Benarasia-Nepali.
36	Sukli ..	Ditto.	..	Ditto.	5′–4″	31	2·6″	0·95″	·96″	0·91″	Ditto.	Ditto.	Ditto.	Profusely developed throughout the length of the cane.	Stout globose ..	Profuse ..	Narrow, erect, slightly bending over.	2′–6″	1·4″	Ditto ..	Ditto.	230 „	Very much diseased and dried up crop, perhaps does not represent varietal characters.
37	Puri ..	Ditto.	..	Ditto.	4′11″	25	3·1″	0·79″	·82″	0·80″	Ditto.	Ditto.	Ditto.	Ditto.	....	Many ..	Erect, rising from different levels.	2′–9″	1·3″	Ditto ..	Ditto.	165 „	Very much diseased and dried up crop, perhaps does not represent varietal characters.

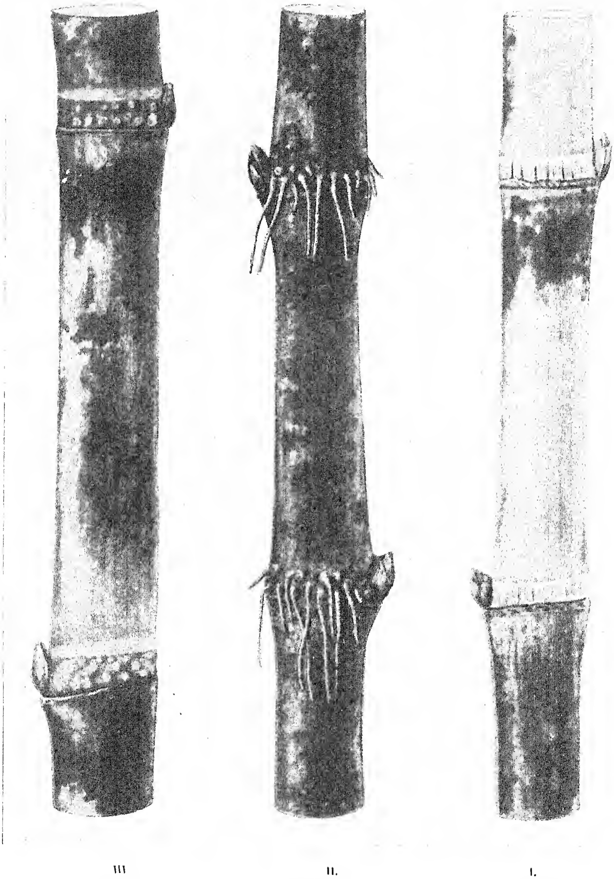
PLATE I.



1. Node.
2. Internode.
3. Wax band.
4. Colour band.
5. Rooting band.
6. Aerial roots.
7. Dormant buds
8. Ligular band.

TO ILLUSTRATE NOMENCLATURE USED IN THIS PAPER.

PLATE II.



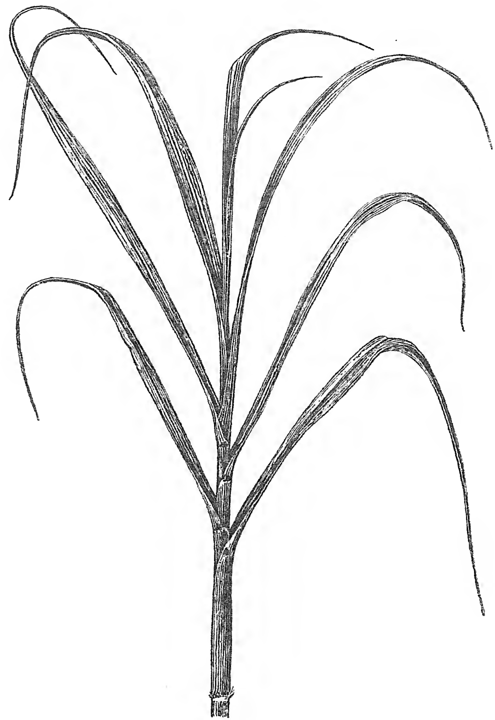
III
MANERIA

II.
BARAUKHA

I.
BANSA

PLATE III.

LEAF CHARACTERS OF THE BUXARIA TYPE.



LEAF CHARACTERS OF THE MANERIA TYPE.

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MEMOIRS OF THE DEPARTMENT OF AGRICULTURE IN INDIA

THE POTATO BLIGHT IN INDIA

BY

JEHANGIR FARDUNJI DASTUR, B.Sc

First Assistant to the Imperial Mycologist

DIEU ET MON DROIT

AGRICULTURAL RESEARCH INSTITUTE, PUSA

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THE POTATO BLIGHT IN INDIA.

BY

JEHANGIR FARDUNJI DASTUR, B.Sc.,

First Assistant to the Imperial Mycologist.

THE "late blight" or "leaf curl" of potato is the most serious disease which attacks the potato. It is widely prevalent in Europe, America and Australia, but fortunately not in India except in the hills. The first outbreak of this disease in the plains was, according to Butler, reported in 1899-1900 from some villages in Bengal. After three or four years it disappeared and since then it was not known in any of the plains in India till 1912-13, when it worked havoc with the potato and tomato crops at Rangpur (Bengal), and destroyed the potato cultivation at Bhagalpur (Bihar).

The cause of the sudden appearance of the "late blight" on potato at Bhagalpur can however be explained. It so happened that the local store of seed potatoes was sold at an abnormally high price, and therefore the cultivators at the time of sowing got seeds from Darjeeling and Naini Tal. *Ph. infestans* (Mont.) de Bary, the cause of the "leaf blight" is present on these hills, and so the majority of the potato tubers, which were obtained from these places for seed purposes, were probably infected with this fungus. It has been shown by Melhus that the mycelium from infected tubers can under favourable circumstances work its way to the sprouts. Therefore, if the tubers obtained from Darjeeling and Naini Tal were already diseased, and if the conditions were favourable, the fungus from infected tubers would pass on to the shoots and there fructify, thereby infecting healthy plants. In the middle of December, 1912, there was some rain and after that nights were foggy and days cloudy; these were favourable conditions for

Phytophthora to spread. A fortnight later field after field was destroyed by *Ph. infestans*. As this disease was not known previously in Bhagalpur district, though potato has been cultivated there for several years, and as seeds were obtained from infected places at the time of sowing, it is very probable that the sudden outbreak for the first time in 1912 may have been due to the use of infected seeds.

The general appearance of the diseased fields was very characteristic. The leaves were almost completely destroyed in eight days by the disease and their rotting had set up a foul smell. The stems were green and stood erect as a rule. They showed many points of local infection and at these places they had turned brown and the epidermis and cortex showed longitudinal cracks. In severe cases of attack the stem gave way at the point of infection. The yield of tubers from diseased fields was abnormally low. The tubers were small in size but there was no supertuberation. When they were picked a large majority of them looked externally healthy, but after a few days' storage, characteristic brown or bluish brown sunken areas were visible; under these sunken areas the tissues had turned brown due to the presence of *Phytophthora* hyphæ. The extent of the browning of the tissues depends upon the time that has elapsed since the attack but more upon the surroundings. If the infected tubers are kept in a warm damp place, the fungus is in very favourable circumstances for overrunning the whole tuber. But if the surroundings be dry there is a check on the growth of the parasite, and the browning of the tissues may then remain only superficial. Whatever be the extent of the attack, the rot caused is always dry, but wet rot generally follows in the wake of *Phytophthora*, on account of putrefactive bacteria and saprophytic fungi getting hold of the diseased tissues.

It is of interest to note that the fields at the Sabour Agricultural College Farm that were sown in the end of November were practically free from the disease. Only a few plants had some of their leaves attacked by the blight; but fields in the near vicinity, sown in October, were totally destroyed. This suggests that if potato

tubers are obtained from infected places, it may be advantageous to sow them late, so that the plants mature in February or March, when the humidity is not so high as in December and January, and therefore even if *Phytophthora* be present, it is not able to make much progress.

Some potatoes picked from infected plants on the Sabour Agricultural College Farm were stored at Pusa. Some of them were kept covered with sand, others were kept uncovered on sand, and the remainder were buried underground. A few were also kept in a cold incubator at 75°F. The extreme moisture in the incubator caused the tubers to germinate immediately, and bacteria, *Rhizoctonia*, *Fusarium* and saprophytic fungi set up a wet rot and the whole lot of potatoes was soon destroyed. Only in one case was I able to trace definitely the presence of *Phytophthora* from among the mass of bacterial and fungal flora that had taken hold of the tuber. During the rains the tubers buried underground germinated prematurely and so naturally soon died, but the sprouts showed no signs of disease. What was left of the stored potato tubers covered and uncovered with sand, after rejecting from time to time those that had been attacked by *Rhizoctonia*, *Fusarium*, bacteria and insects, were planted in Pusa in October, 1913. They gave a perfectly healthy crop.

On the Sabour Agricultural College Farm tubers picked from diseased fields were used as seeds last year, and gave a crop free from *Phytophthora*, also in Bhagalpur district some cultivators used the same fields and the same affected potatoes from the 1913-14 crop without any bad effect. Again on Rangpur Farm one potato plot that was infected by *Ph. infestans* in 1912 grew a healthy crop of potatoes in 1913.

The above facts show that if potato tubers obtained from blighted fields are allowed to pass some part of a summer on the plains, these tubers will give a healthy crop and that the fungus is not able to survive the summer temperature even in the soil. The death of my pure cultures of *Ph. infestans* in summer also shows that this parasite cannot bear the heat of the plains. This renders

the appearance of "late blight" in 1912 at Bhagalpur more intelligible. In normal years small amounts of hill seed may be imported and probably experience sufficient heat on the plains to give a healthy crop. In 1912, however, the shortage of local seed perhaps necessitated the importation of hill seed relatively late in the season, in which case the imported seed might not have been subjected to sufficient heat to kill the fungus.

The remedial measures that suggest themselves from the study of this disease are the following:—

(1) Potatoes to be used as seeds should be obtained, if possible, from places where this disease is not known.

(2) If potato seeds are obtained from places not definitely known to be free from this disease, they should be got in time to allow them to pass a poition of the summer on the plains.

(3) If potato seeds are got from infected or suspected localities after the summer has passed away, they should be sown late in November.

Microscopic Characters of the Fungus.

The general external morphology of the potato fungus is too well known to need repetition. But the internal morphology is of special interest as the observations of the various workers are discordant. De Bary, who has studied this parasite in such great detail and with such accuracy that the investigators who followed have not much to add, states that in the leaves the mycelium does not produce haustoria. In fact he considers *Ph. infestans* (Mont.) de Bary as the only species that has no haustoria, at least in the leaves. In tubers he has undoubtedly seen haustoria as has been pointed out by Mangin. De Bary says that in potato tubers, attacked by *Ph. infestans*, mycelial branches penetrate the host cell, but these branches hardly deserve a special name. Workers after de Bary, it seems, took for granted the absence of haustoria till Mangin, in 1895, proved their existence. Wehmer in 1897 saw

haustoria in potato tubers but he makes only a passing mention of them. In 1903 Delacroix confirmed Mangin's observations and in 1912, Jones, Giddings and Lutman followed suit. Appel and Kreitz studied this fungus in 1907 but they make no mention of either the presence or absence of haustoria and their drawing does not show them. In potato tubers I have found haustoria without any difficulty, even unstained free hand razor sections have clearly shown their presence in the affected cells (Figs. 1 to 7). Iodine or Bismark Brown or Congo Red shows them off more clearly. If the sections, without even any previous treatment with eau de Javel, are boiled with lactic acid and then warmed with cotton blue, washed and again boiled with lactic acid they show the presence of haustoria in the cells. The mycelium takes a blue colour but the tissues remain unstained. Haustoria in tubers are at first small and convex protuberances from the sides of the parent hypha; the cell wall forms a swelling at the point of attack which projects into the cavity of the host cell. As the haustorium grows it becomes either globoid, ovoid, finger-shaped or arched; it is either simple or branched.

With the growth of the haustorium, the sheath, which is round it and which appears to be a direct continuation of the cell wall of the host cell, keeps pace at least for some time, and gets more and more distended into the cell cavity. The formation of the sheath resembles rather that described by Grant Smith in *Erysiphe* than that described by Butler in *Pythium palmivorum*, but the persistence of a cellulose collar at the base of the haustorium, as in *Erysiphe*, has not been observed. This sheath either dissolves under the action of some toxic or enzymic substance that may be produced by the haustorium or not being able to grow further, as fast as the haustorium, gets ruptured (Figs. 5, 8 and 9). It is not essential for the haustorium to penetrate the enveloping sheath, for the former can, even when thus surrounded, draw upon the nutritive material contained in the host cell. Von Guttenberg has shown that the haustorium of *Ustilago Maydis* (D. C.) Corda, though surrounded by a cellulose sheath, still attracts the nucleus of the host cell towards it;

Leitgeb has shown that a parasitic fungus can attack the plasmatic contents of the host cell through its cell walls. Two or more haustoria have been frequently found surrounded by the same vesicle (Fig. 3). Mangin has shown the presence of the vesicle surrounding a haustorium in many *Peronosporaceæ* but he does not say if he has seen any in *Ph. infestans,* at least his figures do not show the vesicle. Delacroix, on the other hand, states that he has never seen it, and therefore thinks that the haustorium merely perforates the cell wall at the point of contact. Jones, Giddings and Lutman, who confirm Delacroix's statement as to the presence of haustoria, make no mention of the presence or absence of a vesicle round the haustorium. All the diseased cells do not necessarily possess haustoria. They are often completely absent; but whenever haustoria are present they are as a rule surrounded by a vesicle. When Delacroix is so emphatic as to the absence of the vesicle it does not seem probable that he has missed seeing it. It is therefore tempting to come tentatively to the conclusion that the presence or absence of the vesicle may have something to do with the different varieties of the cultivated potato. It would be interesting to examine several varieties affected with the blight to see how far this is true.

Mangin has found filiform haustoria in the affected cells in diseased leaves of the potato plant. Delacroix has also found similar haustoria. I have not examined fresh diseased leaves and free hand razor sections of old leaves and those preserved in spirit are not good enough to show the relation of the parasite to the host tissues. But if spirit preserved or dried leaves are first boiled with 3 per cent. caustic potash and after washing them with water if they are stained for about five minutes with a concentrated aquatic solution of rosazurin, the tissues when macerated on the slide show clearly the presence of filiform haustoria, quite different from those found in the tubers (Figs. 11-14). These haustoria in the leaves have also shown the presence of the vesicle surrounding them but not so often as those found in the tubers. Mangin records that different host plants of *Ph. infestans* (Mont.) de Bary, bear different sorts of haustoria, and, therefore, he says that it is not possible to

identify this fungus from the haustoria in absence of the fructification. Delacroix disagrees with him and points out that the haustoria in the diseased potato tubers are identical with those found in a diseased tomato fruit. I have had no opportunity to examine diseased tomato fruits, but haustoria in the stem of the tomato plant (Figs. 8-10) resemble those found in the potato tuber and those seen in the potato leaves agree in shape with those in the tomato leaf (Fig. 15) but the latter are longer.

The mycelium of *Ph. infestans* (Mont.) de Bary shows in the leaves, but not in the tubers, the ingrowths and plugs which Mangin considers to be characteristic of the *Peronosporaceæ* and to be composed of callose. In a previous paper I have shown them, in *Ph. parasitica* Dast., to be composed of cellulose and not of callose. These ingrowths and plugs I have found in the potato fungus also to be of cellulose constitution. They are not dissolved by boiling with caustic potash and give cellulose reactions.

The cell walls between which the mycelium winds its way are affected by the fungus, at least in the tuber. They no longer give the characteristic cellulose reactions with Schulze's Solution, iodine and phosphoric acid and hæmatoxylin, such as are obtained in the normal tissues of the host.

From the literature which I have been able to consult it appears that Appel and Kreiz have observed changes in the starch grains of diseased cells of potato tubers. Appel and Kreiz's drawing shows that some of the starch grains of diseased cells have some of the eccentric markings of the grain highly prominent. I find that the fungus has some action, possibly some dissolving action, on starch grains. In a diseased cell, two kinds of starch grains are occasionally found. One kind contains the normal starch grain, globoid or ovoid in shape with a distinct hilum with fine eccentric markings and with smooth outline. The other kind consists of starch grains the shape of which is distorted (Fig. 16). They are less broad than the normal ones. The outline is corrugated, their hilum is not prominent and their eccentric markings have lost their fineness

and stand out boldly and are not so close to each other as in the normal starch grains. These deformed starch grains seem to be the result of the dissolving action of some enzymic substance that the fungus may be producing. These starch grains do not seem to be chemically changed for they respond normally to the ordinary chemical tests.

W. G. Smith's discovery of oospores of *Ph. infestans* in rotting stem and tubers of potato is at this moment merely of historical interest. When this discovery was announced, de Bary challenged the accuracy of the worker, and subsequent investigations have shown de Bary to be in the right. The oospores obtained by Clinton and Pethybridge in pure cultures have proved without doubt that W. G. Smith never saw the oospores of the potato fungus. Other investigators have followed W. G. Smith's method but they have failed to get his results. From January 1913 to June 1914, I have kept fresh diseased material under moist conditions and from time to time I have examined this material but have never found any of the resting spores found by W. G. Smith.

In February 1913, *Ph. infestans* was taken into pure culture. The conidia bearing mycelium was picked on a sterile needle and was used for inoculating French bean juice agar and Oat juice agar tubes. Aseptic slabs cut from the diseased portions of the tuber were also used in inoculating slants of the above agar media. On French bean juice agar the growth was very poor. Oat juice agar gave a fairly good growth, so also did sterilized potato slabs but still the fungus never seemed to thrive well in its saprophytic surroundings. I am inclined to believe that the quality of the media used was not the only factor which was responsible for the poor growth of the fungus, but that the temperature also had not a little to do with the growth. As the summer approached the growth became poorer and poorer and new subcultures showed very little activity of growth and the fungus ultimately succumbed to the heat of April and May. The fungus lived in culture for such a short time that no conclusion can be come to as to the relative value of different media. Sporangia were not observed in any cultures. No oospores were

produced, but in some of the cultures were found amber coloured, thick walled, globoid or pyriform swollen bodies, borne laterally or terminally on very broad stalks (Figs. 17-20). These swollen heads are cut off from the hypha by a septum and contain dense granular protoplasm with big irregularly formed oil globules. They were found in cultures growing in Oat juice agar and on the mycelium produced from the aseptically cut slabs used for inoculating agar tubes. Sometimes by the bifurcation of the stalk two such swollen bodies are produced together (Fig. 18). Clinton has found that the potato fungus in culture produces very frequently oogonia without antheridia. Judging from his photomicrographs, these oogonia very much resemble the swollen bodies I have found. But there are some very important differences. Clinton's oogonia have their wall thickened by the deposition on the outside of the original coat, and the protoplasmic contents of the oogonium contract to form the oosphere. In the swollen bodies under study I have never seen the formation of the oosphere nor the thickening on the outside of the original coat. The protoplasm has always been found to fill them completely. Their wall has always remained smooth and amber coloured. Pethybridge has also found oogonia without antheridia but these oogonia have produced parthenogenetic oospores. According to him a very characteristic feature of these oogonia is the reddish brown colouring matter in its walls. In this respect Clinton and Pethybridge are in agreement. The last author has also found these oogonia to be "distinctly brittle." This offers another point of difference, the swollen bodies found by me being not brittle. Pethybridge, like Clinton, has found the irregular thickening round the oogonium but this he thinks is an optical illusion due to the diffusion of colouring matter in the surrounding medium. According to Clinton the oogonia vary between 34 and 50μ and according to Pethybridge they measure 31 to 40μ. The swollen bodies found by me measure 24 to 38μ. On account of these differences, I do not think these swollen bodies are either parthenogenetic oospores or oogonia without antheridia. I am inclined to consider them as resting conidia or chlamydospores resembling those found by

Butler and by Shaw in *Pythium palmivorum* Butl., by me in *Ph. parasitica* Dast., and in *Ph. Faberi* Maub., and by Butler and Kulkarni in *Ph. Colocasiæ* Rac. In general appearance these resting conidia and those of *Ph. infestans* look very much alike. In *Ph. parasitica* I have shown that the outer coat is of cellulose in constitution, and in this respect the resting conidia of the potato fungus agree with them for the outer coat of the former has also been found to give cellulose reactions. Pethybridge's figures 4 and 5 of Plate XLVI, and the photomicrographs of Clinton, Plate XXXVIII, Figs. B, F and H so much resemble my drawings that I have doubts if they are illustrations of immature oogonia without antheridia. There is no doubt that Pethybridge has seen parthenogenetic oospores, but in addition to these oospores, it is probable he has seen resting conidia which he mistakes for the former. Jones, Giddings and Lutman have also found these swollen bodies and they consider them to be "resting spores."

SUMMARY.

(1) The "late blight" or "leaf curl" of potato is not well known on the Indian plains, though it is present on the hills. This disease on the plains was first found in 1899-1900 in some villages of Bengal. In about three years it disappeared from these villages, but in 1912-13 potato and tomato crops at Rangpur and Bhagalpur were destroyed by this pest.

(2) The outbreak of "late blight" at Bhagalpur may be attributed to the use of infected seeds obtained, at the time of sowing, from Darjeeling and Naini Tal where this disease is of annual occurrence.

(3) At Bhagalpur, this disease was virulent enough to destroy healthy fields within a week. Its presence could be recognised from a distance by the foul smell emitted by the rotting of attacked leaves. The stems were found to be as a rule green and erect but denuded of almost all their foliage. They showed points of local infection and in severe cases they gave way at these points. The yield of tubers from diseased fields was very low ; they were smaller in size but they showed no supertuberation.

(4) The majority of potatoes picked from diseased fields looked apparently healthy but when stored, the presence of the fungus was made evident by the appearance of depressed brown or bluish brown areas. The rot produced is always dry, the extent of the rot depending upon storage conditions.

(5) Experiments have shown that potatoes obtained from diseased fields at Bhagalpur gave healthy crops the next season even when sown on infected fields of the previous season. Potato seeds obtained from healthy localities were successfully grown on infected fields.

(6) These experiments and the death of pure cultures of the fungus in summer show that the heat of the plains is sufficient to kill the parasite. Therefore, potato seeds from infected localities should be obtained in time to allow the seeds to pass some part of the summer on the plains.

(7) The mycelium is intercellular and sends forth distinct haustoria in the affected cells. The haustoria are surrounded by a vesicle which is a direct continuation of the cell wall of the host cell. The cell walls between which the mycelium runs turn brown and do not give cellulose reactions. The fungus seems to have some dissolving action on starch grains contained in the host cells. These starch grains show distinct corrugation and are deformed in shape.

(8) In pure cultures, grown on artificial media, thick-walled, globoid or pyriform smooth walled bodies, borne laterally or terminally on broad stalks and amber in colour are produced. These are to be considered, in the author's opinion, as resting conidia similar to those found in *Pythium palmivorum* Butl., *Phytophthora parasitica* Dast., *Ph. Colocasiæ* Rac. and *Ph. Faberi* Maub., and not parthenogenetic oospores.

PUSA :
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EXPLANATION OF PLATE.

Figs. 1—7. Haustoria of *Phytophthora infestans* from potato tubers. X 937.
The vesicles round the haustoria are clearly seen. In Fig. 5 the vesicle is partly dissolved.
Fig. 2 shows a branched haustorium. Fig. 3 shows the vesicle surrounding two haustoria one of which is branched.

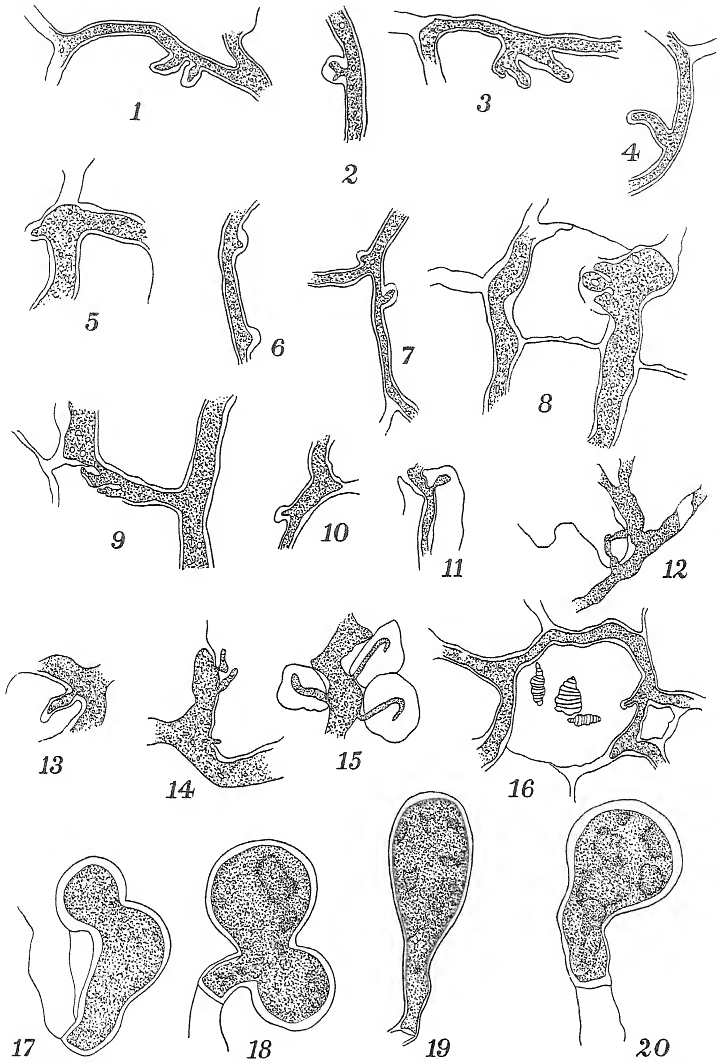
„ 8—10. Haustoria from the stem of a tomato plant. X 937.
Figs. 8 and 9 show the vesicle round the haustoria partly dissolved.

„ 11—14. Haustoria from potato leaves. Figs. 11 and 12. X 750. Figs. 13 and 14. X 1160.
Fig. 12 also shows the cellulose plug in the hypha.
In Fig. 13 the vesicle round the haustorium is seen.

Fig. 15. Haustoria from the leaf of a tomato plant. X 1160.

„ 16. A diseased cell of a potato tuber containing deformed starch granules. X 750.

Figs. 17—20. "Resting" conidia of *Ph. infestans* from pure cultures. X 960.
Fig. 18 shows a bifurcated "resting" conidium.



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MEMOIRS OF THE DEPARTMENT OF AGRICULTURE IN INDIA

THE GENUS *RHIZOCTONIA* IN INDIA

BY

F. J. F. SHAW, B.Sc. (Lond)

AND

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DIEU ET MON DROIT

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THE GENUS *RHIZOCTONIA* IN INDIA.

BY

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THE genus *Rhizoctonia* has attracted considerable attention in recent years in India, Europe and, particularly, in America. The previous work[1] in this country was concerned chiefly with the form *R. Solani* Kühn, which was shown to be the cause of extensive damage to jute, cotton, and other crops. Moreover cross inoculations between different hosts revealed the presence of a specialization in the parasitism of this fungus analogous to that so well known in *Puccinia* and *Erysiphe*. The present paper describes two species of *Rhizoctonia* of some economic importance in India and presenting a few points of general scientific interest. It is unnecessary to recapitulate here the historical information relating to this genus which has been summarized in a previous communication.[1]

Rhizoctonia Napi West.

In January 1914, the state of the mustard crop in one field of the Pusa Farm indicated the presence of a virulent disease. The crop was about three feet high and was well developed, but the stems, pods, leaves, in fact all parts of the plant, were covered with a thick white growth of mycelium. This produced a dry rot at the nfected area and as a result a large number of plants were lying prone on the ground with bent and broken stems. In the majority of cases the patches of mycelium contained sclerotia. These were large white aggregations of hyphæ, which ultimately turned black on the outside; they were common in the cavity of the pith and inside the pods. The striking point about this parasite was its omnivorous nature; in fact

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[1] Shaw, F. J. F. "Morphology and Parasitism of Rhizoctonia," *Mem. Dept. Agri. India, Botanical series*, Vol. IV, No. 6, 1912.

the fungus appeared to spread upon all living plants in the vicinity of the mustard as the following list of hosts will show :—

Amaranthus tristis	*Hordeum vulgare*
Argemone mexicana	*Lathyrus sativus*
Avena sativa	*Lens esculenta*
Beta bengalensis	*Leucas*
Brassica campestris var. *glauca*	*Linum usitatissimum*
Calamintha	*Medicago lupulina*
Cannabis sativa	*Pisum sativum*
Chenopodium album	*Scoparia dulcis*
Cicer arietinum	*Triticum vulgare*
Cincus arvensis	*Vicia hirsuta*
Fumaria parviflora	

A second outbreak of this disease took place in February 1915, when a small field of gram was attacked. In this case the fungus occurred chiefly on the pods (Pl. 1, fig. 2.), which turned white and became filled with the fungus. The same parasite has also been found attacking cruciferous plants (e.g., *Erysimum*) in gardens in which the soil had been heavily manured with cattle manure, and the fact that the field of mustard on which it first appeared in Pusa had also received heavy applications of organic manures suggests that the outbreak of the disease is favoured by this treatment. The infection might pass into the soil with the manure or the latter may merely create the conditions which are necessary for the rapid development of a fungus hitherto dormant in the soil; the lowering of the power of disease resistance in a crop which results from heavy nitrogenous manuring is well known.

Inoculations upon glucose agar medium[1] resulted in a rapid growth of the fungus and the production of numerous sclerotia (Pl. VI, fig. 3). The hyphæ were of the typical *Rhizoctonia* form, the branches of the mycelium being characterized by the basal constriction and transverse wall (Pl. V, fig. 1) so well known in other species; the cells were about 160μ long and 16μ broad but showed great variation in size. The sclerotia were irregular round bodies black on the outside and white in the interior (Pl. II, figs. 2, 3); they were about

[1]

Extract of Lemco	4 grms.
Sodium chloride	5 ,,
Peptone	10 ,,
Glucose	20 ,,
Agar	15 ,,
Water	1000 c.c.

2 to 5 mm. in diameter, but by several sclerotia adhering together composite bodies up to 1 or 2 cm. may be formed. The sclerotia consist of hyphæ tightly woven together, of which the outer two or three layers have divided up into small thick-walled black rectangular cells forming a protective covering to the softer tissues of the interior (Pl. II, fig. 3). A comparison of the sclerotia and hyphæ with the known species of *Rhizoctonia* suggested that this parasite was *Rhizoctonia Napi* West, a fungus which was first identified upon *Brassica Napus* at Courtrai in Belgium.[1] Growth upon glucose agar was very vigorous and the same may be said of French bean[2] and oat juice[2] agar; on the two latter media a spore form was produced, the presence of which was particularly interesting in view of the recent work on the nature of *Rhizoctonia*. Modern evidence[3] has shown that the perfect stage of *Rhizoctonia* is, in some forms at least, a basidiomycete belonging to the genus *Corticium*. The spore form produced on French bean agar cultures of *R. Napi* has however no relation to *Corticium*. A fertile hypha of the mycelium bears numerous short branches which terminate in small spherical colourless conidia (Pl. V, figs. 2, 3, 4); sometimes the conidiophores branch again themselves, the ends of the secondary branches bearing the spores. In other cases the conidiophores are collected in a dense bushy terminal growth at the apex of a thick hypha. The whole morphology of this fertile stage strongly suggests the genus *Botrytis*. The short thick conidiophores are swollen at the base and taper to a point at the distal end bearing the spore. The spores are spherical hyaline bodies about 4μ in diameter in the examples illustrated in this paper, but cases have been observed in old cultures of $8\text{-}12\mu$ in diameter. The conidiophores vary in length from 6μ in the case of short unbranched individuals up to 24μ in the longer branched forms.

The spore form very rarely occurred on glucose agar, although numerous inoculations were made upon this medium from a mycelium containing fertile branches. A sub-culture upon French bean agar from a very young glucose agar culture, containing only about $\frac{1}{4}$ in growth of typical hyphæ, produced the spore

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[1] Saccardo, P. *Syll. Fung.*, Vol. XIV, p. 1176, 1899.

[2] Take 50 grms. of crushed French beans or oats and boil with 300 c.c. water for 1 hour and strain through a wire gauze. Dissolve 10 grms. of agar in 200 c.c. water, add decoction and heat to mix thoroughly.

[3] Rolfs, F. M. *Colorado Agric. Coll. Bull.* 70, 1902, *Bull.* 91, 1904.

Güssow, H. T. Bei trag zur kenntniss des Kartoffel Grindes. *Corticium vagum* B. C. var. *solani* Burt. *Zeits f. Pflanzenkrankh*, Vol. XVI, 1906.

Pethybridge, G. H. "Investigations on Potato Diseases." *Journ. Dept. Agric. Tech. Inst., Ireland*, Vol. XI, 1910-11.

Shaw, *loc. cit.*

form although the parent glucose culture never did so; in only one case, that of a culture from a diseased gram plant to glucose agar, did the spore form occur on this medium. Moreover the fact that in culture it was possible to trace the fertile hyphæ in organic connection with hyphæ which had the typical branching of *Rhizoctonia* hyphæ (Pl. V, fig. 4) shows that the fertile form is part of the sclerotial fungus and not an impurity in culture as might have been suspected.

The growth of the fungus in agar culture continued quite vigorously up to the month of April. About this time it was noticed that the vigour of subcultures was declining, and in some cases no growth was obtained. At the same time the mycelium of older cultures began to turn black. Various devices were tried to induce the fungus to grow and it was finally discovered that temperature was the limiting factor. On transferring the cultures to a cool incubator at 23°C. growth continued in a normal manner; the cultures were maintained in the cool incubator through the hot weather and were finally resumed in the open air in October. The average monthly temperature of the Mycological Laboratory during 1914 at Pusa was as follows:—

	°C.		°C.
January	.. 17	July	.. 31
February.. ..	.. 22	August	.. 28
March	.. 26	September ..	.. 29
April	.. 29	October ..	.. 27
May	.. 30	November ..	.. 23
June	.. 32	December ..	.. 18

The maximum temperature for the growth of *R. Napi* would therefore seem to be about 29°C.

In order to test the temperature relations of this fungus an experiment was made in which cultures were placed in incubators at different temperatures. *viz.*, 23°, 29°, 32°C. At the lower temperature 23°C. growth was strong both upon glucose agar and French bean agar. At 29°C growth was much weaker and sclerotial formation was slight; at 32°C growth was practically entirely inhibited. At the high temperatures the fungus turns a brown black colour in culture. This experiment therefore indicates 29°C as about the point at which the degree of temperature has a markedly inhibitory effect on the growth of *R. Napi*, while at 32°C. and upwards growth may be considered impossible. Since exposure to a temperature of 29°C. and upwards inhibits the growth of the fungus it is obvious that it can only occur as a serious parasite on the plains during the cold weather. On the other hand, it is by no means

certain that the heat of the hot weather and rains is sufficient to kill the fungus even when endured for a long period. During the month of June cultures ceased growth when kept for several weeks at the ordinary laboratory temperature (from 29·5—32°C.) but commenced growth again when placed in an incubator at 20°C. In a second experiment cultures were kept at 29°C. and 32°C. for 48 hours, at the expiration of which there was a very slight growth in the tube at 29°C., and were then transferred to a temperature of 23°C. and examined again after 48 hours. Growth was resumed strongly at the lower temperature but the tube which had been kept at 32°C. did not give such a good growth as that from 29°C.

The temperature of the soil in India has recently been the subject of investigation[1] and the following statement shows the approximate average temperatures throughout the year at depths of 2″, 6″, 12″, 18″, 24″ in the soil at Pusa.

Month	2″		6″		12″		18″		24″	
	Maximum °C.	Minimum °C.	Maximum °C.	Minimum °C	Maximum °C.	Minimum °C	Maximum °C.	Minimum °C.	Maximum °C.	Minimum °C.
January	22	11	19	14	16	17	17	17	18	18
February	27	15	23	17	21	19	20	20	20	20
March	33	17	28	20	25	22	23	23	23	23
April	36	22	31	24	28	26	27	27	27	27
May	39	28	35	30	32	31	31	31	31	31
June	39	29	35	31	34	32	33	33	33	33
July	35	28	33	29	30	30	31	31	31	31
August	35	28	32	29	31	31	31	31	31	31
September	35	27	33	29	31	30	30	23	31	31
October...	35	24	32	27	30	29	29	29	30	30
November	27	17	25	20	23	22	23	23	24	24
December	23	12	20	15	18	18	19	19	20	20

It is clear from the above table that *R. Napi* is incapable of growth in the first 24 inches of Pusa soil from May to October, and indeed the high temperatures experienced in the upper layers of the soil might suffice to kill the fungus, but, from the facts detailed above, it is evident that the fungus might be capable of withstanding prolonged exposure to the temperatures which occur at depths below 18″ from the surface, and thus surviving until the next cold weather when vegetative growth is again possible. We must be cautious however in making a comparison between a fungus enduring a high temperature in a culture tube with an abundant supply of food and moisture and one meeting the same degree of temperature in the Indian soil under natural conditions when extremes of heat and drought frequently coincide.

[1] Leather J. W. "Soil Temperatures." *Mem. Dept. Agr. India, Chemical series,* Vol. IV, No. 2, 1915.

Infections from agar culture, upon mustard (Pl. I, fig. 1) and gram plants were invariably successful, the death of the host taking place in every case; the fungus formed a copious growth on the exterior of the stem, as well as penetrating within, and numerous sclerotia, together with the spore stage, were formed. From the diseased plants the fungus was again isolated in pure cultures where it again produced the spore form.

Rhizoctonia destruens Tass.

This fungus was first noticed in July, 1912, when it appeared on rotting potato tubers sent from storage at Bankipore. The diseased potatoes were rather soft and showed thick white strands of mycelium and brown sclerotia on the external surface. The tubers were incubated in a moist chamber and gave a very copious growth of white hyphæ (Pl. IV, fig. 2); the hyphæ showed a tendency to become united in strands which made the mycelium very tough and gave it a fairly characteristic appearance. The branching of the hyphæ followed the characteristic form of *Rhizoctonia* and clamp connections were very numerous. The sclerotia were formed in abundance, were light brown in colour and of fairly regular spherical shape about 1-2 mm. (Pl. IV, figs. 2, 3) in diameter. In section the sclerotia showed a white interior, surrounded by a thin brown outer layer consisting of two or three hyphæ divided up into rectangular thick walled cells. At the time when this parasite was first collected it was not identified with any certainty; the fungus was obviously not the same as the *R. Solani* Kühn, which had been found previously on rotting potatoes, but the matter was finally decided in February, 1913 when specimens of *Delphinium*, suffering from the same fungus, were received from Alipore, Calcutta. The fungus was obtained in culture from the *Delphinium* and showed a strict agreement with that on the potato. A comparison of the parasite with the description of *R. destruens*[1] Tass., first described by Tassi on *Delphinium* in the botanical garden at Siena in Italy, left no doubt as to the identity of the fungus. Infections from glucose agar upon healthy uninjured Delphinium plants (Pl. III, fig. 1) gave 100% of deaths in a few days. Since making the above observations the fungus has appeared as a virulent parasite of different crops in various parts of India.

(1) Betel vine (*Piper betle*) is seriously damaged both in Bengal and Bombay (Pl. III, fig. 2). In Bengal the disease occurs in the vicinity of Bogra, during the rainy season, and in Bombay it is common in the district of Nasik and also occurs in Dharwar and Belgaum. The fungus attacks the plants at about the level of the collar (Pl. III, fig. 2) and below the

[1] Saccardo, P. *Syll. Fung.*, Vol. XVI, p. 1109.

soil, where it sets up an extensive rot in the stem swiftly leading to the death of the whole vegetative portion above ground. The whole of the rotted portions of the plant become covered with a thick weft of hyphæ with numerous sclerotia. From a diseased plant it is easy to obtain the fungus in culture; its form in culture (Pl. VI, fig. 1) does not differ from that on the host and agrees with that seen previously upon potato and *Delphinium*. Cultures of the fungus from Bombay Presidency sometimes showed the sclerotia slightly stalked and the same thing was also noticed on diseased betel vines from Bogra. This agrees exactly with Tassi's original description as given in Saccardo "Tuberculis ...... interdum minute umbilicatis." Sometimes this feature is so marked that the sclerotia take the form of club shaped bodies, recalling the sclerotia of *Xylaria*, in this state they often remain white in colour and never become brown; occasionally the sclerotia become fastened together in clumps—a common feature in this genus. Inoculations from agar cultures upon betel vine were very successful both at Pusa and at Poona, the infected plants dying in every case with a copious development of the fungus. No trace of a perfect stage was ever found. A basidiomycete, identified with *Dædalea*, was found closely associated with *Rhizoctonia destruens* on betel vine, and on stems of *Sesbania ægyptica*, grown as supports for the vine, both in Nasik and Belgaum. But no organic connection could be traced between the two nor did successful inoculation with *R. destruens* on *Sesbania* succeed in producing the *Dædalea*.

(2) Potato (*Solanum tuberosum*). As already mentioned the potato is liable to disease owing to this fungus (Pl. IV, figs. 2, 3). In Bihar the parasite has appeared chiefly as a rot of stored potato, but in the vicinity of Poona it is a frequent cause of trouble to the growing crop. The mode of attack is exactly similar to that observed in the betel vine, the portion of the stem at the ground level, and the subterranean parts of the plant, becoming covered with a weft of hyphæ with sclerotia (Pl. IV, fig. 3). This is followed by the rotting of these parts and by the drying and browning of the leaves; the attack is usually late about six weeks after the planting of the sets. The tubers from diseased plants are apparently sound although smaller than those from healthy plants but cases have been found in which apparently sound tubers from diseased plants have been infected with the mycelium through their attachment to the parent stem. The experience with stored potatoes in Bihar shows that tubers from a diseased crop are probably infected with the fungus. The use of a wash of standard corrosive sublimate, combined with proper precautions in storage, would certainly go far towards lessening this disease in store.

Inoculations upon potato tubers were uniformly successful, when the infection was made upon the cut surface of a tuber. In unwounded tubers although the fungus spread over the surface of the tuber the external corky covering was sufficient in many cases to prevent penetration. Sometimes, however, penetration took place through the eyes, or even through the lenticels. The same results were obtained whether the fungus used for inoculation had been isolated from a diseased potato or from the betel vine.

(3) Suran (*Amorphophallus campanulatus*). This crop is, in Poona, frequently damaged by *R. destruens*; the corms rot completely in the soil and the shoots die later (Pl. IV, fig. 1). In culture the fungus from suran is indistinguishable from that of the other hosts and inoculations gave similar results to those on the potato. In every case in which the outer surface of the corm was wounded before making the infection the fungus established itself rapidly and the death of the host soon took place. If, however, the outer corky surface of the corm were unbroken successful infections were rare. Cross inoculations from potato and betel vine yielded the same results.

(4) Lucerne (*Medicago sativa*) has been found suffering from *R. destruens* at Surat, but the damage was not extensive and the parasite is unusual on this host. The fungus attacks the plants at the collar, setting up a rot of the stem and leading to rapid death of the aerial portion.

(5) Groundnut (*Arachis hypogæa*) has also been observed to suffer from *R. destruens* when sown on land which had previously borne a *Rhizoctonia* infected potato crop.

(6) Rice (*Oryza sativa*). Although *R. destruens* is not at present known as a parasite of rice in India it has been collected on this host in Java during the last two years.

In November, 1913, some rice-seedlings, with brown mustard-seedlike sclerotia formed on them at the collar, were collected at Buitenzorg, Java. The rice-seedlings were dying in large numbers, presumably as a result of the attack of this sclerotium-producing fungus.

The sclerotia were used for obtaining pure cultures on glucose-peptone-agar medium, with the result that a fungus was obtained which was indistinguishable in any particular from the *Rhizoctonia destruens* on betel vine and suran; no spore form has been obtained though the fungus has been in cultivation for over a year. Some inoculations were carried out with pure cultures from the rice sclerotia on suran, potato and rice as hosts. The two former hosts were successfully infected but the results with rice were inconclusive.

Several sclerotia-forming fungi are known as parasites of the rice plant[1] but up to now all have been members of the genus *Sclerotium*, namely, *Sclerotium Oryzæ* Catt., *Sclerotium glumale* Ces. and *Sclerotium irregulare* Miy., and can easily be distinguished from *R. destruens* Tass. The most recent work on a sclerotial parasite of paddy is that of Van der Wolk[2] from Java. From this author's description and figures it is not possible to form any clear picture of the characteristics of the sclerotia and mycelium of his fungus, which he has elevated into a new species under the name *Sclerotium omnivorum*. Van der Wolk also states that two spore forms, one a species of *Ascobolus*, were connected with his sclerotial fungus ; as however the evidence on which this was based was derived from cultures consisting of pans of rotting vegetable matter, from which it is admitted that saprophytic bacteria were not excluded, it is difficult to regard the author's point as satisfactorily established.

There is no evidence of any specialization in the parasitism of *R. destruens*. Cross inoculations with the form from one host plant on to another host were invariably successful. *Delphinium* is susceptible to the attack of all forms and successful inoculations on unwounded plants were obtained with *R. destruens* from betel vine, potato and lucerne. On potato and suran the fungus appears to be a weaker parasite than on betel vine and *Delphinium* : the former hosts requiring a wound in their superficial tissues before the fungus can penetrate. Jowar seedlings are also attacked by *R. destruens* and inoculations in the laboratory gave 60% of deaths ; moreover a basidiomycete resembling a *Hypochnus* was found associated with the *Rhizoctonia* on the jowar. In view of the connection between other species of *Rhizoctonia* and the genus *Corticium*[3] this result was very suggestive, but, unfortunately, all attempts to repeat this experiment from the point of view of producing the basidiomycete, were unsuccessful.

METHODS OF TREATMENT AGAINST *Rhizoctonia* DISEASE.

Fungi such as *Rhizoctonia* possess a method of perennating from one season to another by means of their sclerotia. It is therefore important to obtain some idea as to the longevity of the sclerotia. The sclerotia of *R. destruens*

[1] Shaw, F. J. F. "Sclerotial Disease of Rice." *Mem. Dept. Agric., India, Bot. Ser.*, Vol. VI, No. 2, 1913.

Miyake, I. Studien über der Pilze der Reispflanze in Japan. *Journ. College of Agric., Tokio*, 1910.

[2] Van der Wolk, P. C. *Rhizostilbella rubra* (n. gen. n. spec.) a by-fruit form of *Ascobolus parasitiens* (nov. spec.) and its connection with the "Sclerotium disease" of certain tropical cultivated plants (*Sclerotium omnivorum*). *Mycologische Centralblatt* Bd. IV, Hft. 5, June, 1914.

[3] Rolfs, Güssow, Pethybridge, Shaw. *loc. cit.*

have been found to germinate when about sixteen months old, but sclerotia kept much longer than this generally failed to germinate. This suggests that rotation of crops, and avoiding a *Rhizoctonia*-susceptible host for a few seasons might be a useful practice, but extensive experiments are necessary to establish the utility of this method of starving the fungus out of the soil. Methods of sterilizing the soil which may be practicable in the laboratory or seed nursery are hardly ever possible in general agriculture; since, however, *R. destruens* is a parasite on *Delphinium* and *Dianthus* it might be worth using a soil fungicide in such cases.

Various methods have been used to sterilize soil against *Rhizoctonia*. In the prevention of damping off of coniferous seedlings, due to *Rhizoctonia* or *Pythium*, the use of commercial sulphuric acid as a soil fungicide is recommended by a number of authors[1]; the best strength seems to be a solution of 1 oz. in 1 gallon of water applied at the rate of 3/16 oz. per square foot. Formalin is often used as a soil fungicide,[2] the strength of the solution is commercial formalin 1 pt. water 50 pts. at the rate of $\frac{1}{2}$ gallon per square foot, and Salmon[3] and Eriksson[4] both suggest the use of a solution of phenol, but sterilization by heat is undoubtedly one of the most efficient methods. In the case of seedling beds steam sterilization by the inverted pan method is strongly recommended by Johnson[2], but the less troublesome and expensive formalin treatment would probably be preferred by most people. A marked instance of the sterilizing effect obtained by heating the surface of the soil is provided in the raising of tobacco seedlings in Pusa.[5] It has been found that in seedling beds which have been so treated the plants are practically immune from a destructive damping off due to a fungus which, under certain conditions, does great damage. There is reason to believe that this particular disease is due to *R. Solani* Kühn. In all cases of sterilization of soil by formalin or by steam it is necessary to remember the secondary effects which may arise

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[1] Spaulding, P. "Treatment of damping off in Coniferous seedlings." *U. S. Dept. Agric. Bureau of Plant Industry, Circ.* No. 4, 1908.

Hartley, Carl. "Use of soil fungicides to prevent damping off in coniferous seedlings." *Proc. Soc. Amer. Foresters*, Vol. VIII, 1912.

Kræmer, H. "Dilute sulphuric acid as a Fungicide." *Proc. Amer. Phil. Soc.*, Vol. XLV, 1906.

[2] Johnson, J. "Control of damping off in Plant beds." *Agric. Expt. Sta. Univ. Wisconsin, Bull.* 31, 1914.

[3] Salmon, E. *Gardeners' Chronicle* 44, p. 1, 1908.

[4] Eriksson, J. Einige Studien über Wurzeltöter. *Centralblatt. f. Bakt. Parasit. Infektionskrank*, Vol. X, 1903.

[5] Howard, A., and Howard, G. L. C. "Improvement of Tobacco Cultivation in Bihar." *Bull.* No. 50, *Agric. Res. Inst., Pusa.*

in soil so treated.[1] In the cultivation of paddy in some parts of the Bombay Presidency the practice of "rabbing,"[2] that is of burning the surface layers of the soil by spreading fire wood and rubbish and igniting it, would not be without some sterilizing effect and might perhaps be extended with advantage to the preparation of land for betel vine.

With crops such as potato and suran, in which portions of subterranean stems are used for seed purposes, there is always the possibility of sowing tubers or corms which have sclerotia adhering to their surface. In these cases treating the seed with some fungicide is a cheap and efficient method of lessening the chances of infection. The effect of corrosive sublimate and of formalin as a seed dip was determined by steeping sclerotia of *R. destruens* for $2\frac{1}{2}$ hours in each and then trying to germinate them on wet blotting paper and in culture tubes.

Fungicides	Strength	Result
Corrosive Sublimate ...	1·0 %	No sclerotia germinated.
" ...	0·1 "	" " "
Formalin	0·5 "	" " "
"	0·25 "	Many germinated after 6 days.
"	0·12 "	All germinated after 2 days.

The number of sclerotia used in each case was about 50. In the controls with untreated sclerotia all the sclerotia germinated in two days. Solutions of copper sulphate proved unreliable as a fungicide in the case of *R. destruens*, and sclerotia which had been immersed for 2 hours in 5, 2·5, 1·25 and 0·5% copper sulphate all germinated in from 24 to 48 hours. The failure of the copper sulphate may have been due to the inability of this solution to penetrate to the interior of the sclerotium ; accordingly, the experiment was repeated with the difference that the vessels containing sclerotia immersed in solutions of copper sulphate were placed under an air pump, at the same time of course a control was carried out under normal atmospheric pressure. Under reduced pressure 5, 2·5, 1·2% copper sulphate prevented the germination of the sclerotia, but 0·5% was not strong enough, and, in this case, germination took place. In the controls under normal atmospheric pressure germination took place after treatment with 0·5 and 1·25% but not after treatment with 5 or 2·5%. This result differed from that obtained in the first experiment, in which even the sclerotia which had been immersed in 5% $CuSo_4$ germinated,

[1] Russell & Pethybridge. *Journ. Board. Agric., London*, XVIII, p. 809, 1912.

[2] Mann, H. H., Joshi, N. V., & Kanitkar, N. V. "Rab system of rice cultivation in Western India." *Mem. Dept. Agric., India, Chemical series*, Vol. II, No. 3, Feb. 1912.

but the relatively greater efficiency of the copper sulphate in the second experiment was probably due to the fact that the sclerotia used were rather younger and possibly did not possess such a well developed outer protective layer.

Strength of Copper Sulph.	Old sclerotia Normal atmospheric pressure	Young sclerotia Normal atmospheric pressure	Young sclerotia Under vacuum
5·0 % ...	Germinated in 48 hours	No germination	No germination
2·5 ,, ...	,, ,, ,, ,,	,, ,,	,, ,,
1·2 ,, ...	,, ,, 24 hours	Germination in 48 hours.	,, ,,
0·5 ,, ...	,, ,, ,, ,,	,, ,,	Very slight germination.

It is evident from these experiments that copper sulphate in strengths below 5% can hardly be considered a reliable fungicide against *R. destruens* and on the whole treatment with a solution of corrosive sublimate is probably the most efficient method of killing such sclerotia as may adhere to a potato tuber or suran corm. It should always be remembered that treatment with a fungicide is intended as an assistance to, and not as a substitute for, hygienic methods in storing.

This result agrees with the conclusions of American investigators who have done extensive field experiments on the treatment of potato tubers againt *Rhizoctonia* disease. Rolfs[1] found that the corrosive sublimate treatment improved the appearance of the crop and gave marked gains when the treated seed was planted on new lands, proving much more efficient than treatment with formalin. The work of Güssow[2] and of McAlpine[3] also bore out this conclusion, while Gloyer[4] has found that neither formaldehyde gas nor formaldehyde solution can be depended upon to kill *Rhizoctonia* sclerotia, but that treatment with 1-2000 solution of corrosive sublimate is an efficient fungicide against *Rhizoctonia*; with formaldehyde gas according to Gloyer there even appears to be some danger of injuring the potatoes. On the other hand other investigators[5] recommend the formalin treatment or a lime sulphur wash as a fungicide against the "dry rot" of Irish potatoes which is due to *Fusarium tuberivorum*. It is unfortunate that these workers did not make a

[1] Rolfs, F. M. *loc. cit.*

[2] Güssow H. T. *Canada Expt. Farm Reports*, 1912, p. 200.

[3] McAlpine, D. *Fungus Diseases of Potato in Australia*, 1911.

[4] Gloyer, W. O. *New York Agric. Expt Sta. Bull.* 369, 370, 1913.

[5] E. Wilcox, G. Link & Venus W. Pool. "Dry Rot of Irish potato." *Bull.* 1 *Agric. Expt. Sta. Nebraska*, 1913.

trial of corrosive sublimate as it would be a great advantage to obtain a method of treatment which would be equally efficient against both *Fusarium* and *Rhizoctonia*. In this connection we must note that yet another fungicide is recommended by Sherbakoff[1] in the treatment of potato scab. Sherbakoff states that mixing sulphur with the soil, at the rate of 450—900 lbs. per acre, has a marked effect in checking this disease but it is by no means certain that the after effects of the sulphur on the fertility of the soil are not more to be dreaded than the loss due to any disease. On the other hand, a seed dressing of napthalene[2] appears to be an efficient and harmless remedy against sore shin in cotton.

There is an apparent discrepancy in the above account between the results of those investigators (Johnson), who found formalin an effective soil fungicide and those (Rolfs, Güssow, Gloyer) who found that it was not so efficient as a disinfectant for potato tubers. It is necessary to bear in mind that Johnson worked with a solution of 1 pt. formalin in 50 pts. water and that Rolfs and Gloyer used a solution of 1 pt. formalin in 240 pts. water. Our experiments have shown that formalin solution of a strength below 0·5% cannot be trusted to kill sclerotia of *R. destruens* but that corrosive sublimate in strengths of 1 pt. in 1000 pts. water is a reliable fungicide. In recommending mercuric chloride as a disinfectant for potato tubers before storing it is necessary to bear in mind that potatoes so treated cannot be safely used for human consumption and the treatment is therefore only suitable in the case of tubers which are intended for seed purposes. Güssow and Shutt[3] have shown that 3 lbs. of potato tubers (13 tubers) treated for 3 hours with 1-2000 corrosive sublimate solution will take up from the solution 0·05 gm. of mercuric bichloride, which is six times the maximum official dose in medicine; potatoes which have been so treated must therefore be regarded as non-edible. The very material reduction in strength of the solution shows that the solution must be renewed fairly often, it is possible that the neglect of this precaution accounts for the supposed failure of corrosive sublimate to prevent the reappearance of disease in certain cases.

Systematic.

In the case of a genus such as *Rhizoctonia*, which is identified by its vegetative characters, it is always possible that we are dealing with an artificial group of which the different species are vegetative stages of widely separate

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[1] Sherbakoff, C. D. *Cornell Univ. Agric. Expt. Sta. Bull.* 350, 1914.
[2] Balls, W. L. "Physiology of simple parasite." *Year-book Khed. Agric. Soc.*, 1905-06,
[3] Güssow, H. T. *Canada Expt. Farm Reports,* 1912, pp. 200—2.

fungi and in which the morphological similarities between the species are accidental; the study of *R. Napi* appears to furnish an example of this.

A disease of *Brassica* was discovered by Frank[1] in 1879 which, in its effects upon the host plant, appears to be indistinguishable from that which we have attributed to *R. Napi* West. The fungus consisted of a dense white mycelium with large black sclerotia which, in section, showed a white interior surrounded by a black outer layer; the spore form was the well-known *Botrytis cinerea* Pers. Comparing the description of the sclerotia of *R. Napi* West with the sclerotia of Frank's fungus one is forced to the conclusion that the two fungi are the same and that they are identical with the fungus described in this paper. It follows from this that the spore form which we obtained is *Botrytis cinerea* Pers. and the criticism will at once arise that this form (Pl. V, figs. 2, 4) differs widely from that which normally occurs in the species. It has, however, been shown that the morphology of *B. cinerea* is closely dependent on the composition of the nutrient medium[2] and a variation of the normal form is known (Beauverie et Guilliermond, p. 281, fig. 6) which agrees exactly with that figured on Plate V of this paper. Additional proof is furnished by the fact that another variation from the normal form of *Botrytis*, in which the swollen ends of hyphæ branch in an umbellate manner (shown in Fig. 1 Beauverie et Guilliermond) is also common in our cultures. The normal method of branching which occurs in the hyphæ figured in this illustration (Fig. 1, Beauverie et Guilliermond) is almost typical of *Rhizoctonia*. Frank states that the sclerotia of *Botrytis cinerea* will germinate in damp sand and give rise to the apothecia of *Sclerotinia Libertiana* Fuck.; up to the present sclerotia of our fungus have not produced any apothecia. Smith[3] throws doubt on the connection between *B. cinerea* and *S. Libertiana* but Istvanffi appears to have obtained satisfactory evidence that they are different stages of the same fungus.

There is a large and convincing body of evidence (Rolfs, Güssow, Shaw) which shows that the fertile stage of at least one species of *Rhizoctonia* is a basidiomycete of the genus *Corticium*; from the present paper, however, it appears that *R. Napi* has its fertile stage in a totally different group and that its inclusion in the genus is an error. In brief this species furnishes an instance of the fact that the genus *Rhizoctonia*, as constituted on purely vegetative

[1] Frank, A. B.—Kampfbuch gegen die Schädlinge unserer Feldfruchte. Berlin, 1897, p. 276.

[2] Beauverie, J. et Guilliermond, A.—Etude sur le structure du *Botrytis cinerea*. *Centralbl. Bakt. Parasit. Infektionskrank*, Vol. X, 1903.

[3] Smith, R. E. *Botrytis* and *Sclerotinia*. *Bot. Gaz*, June, 1900.

„ „ Parasitism of *Botrytis cinerea*. *Bot. Gaz*. June, 1902.

characters, is an artificial group. It will probably be better to limit the use of the name to the sclerotial stages of those fungi with a perfect stage in the genus *Corticium*.

The point in which we differ widely from other workers on this genus is in the facility with which they have assumed that the *Rhizoctonia* on potato is always to be identified with *R. Solani* Kühn. The practice of multiplying the species of a genus according to the number of hosts on which it is parasitic has been responsible, in some genera, for a great deal of unnecessary complexity, but the converse process whereby different species of a genus, all parasitic on the same host, are referred to under a single specific name, derived from the host, is equally confusing. The naming of a species after the host plant on which it is parasitic (*e.g. R. Solani* on *Solanum tuberosum*) is apt to give rise to an attitude of mind which automatically refers that genus, when parasitic on that particular host, always to the one species. In a previous publication we have given reasons for believing that the fungus *R. Solani* Kühn is identical with the form of *Rhizoctonia* having small black sclerotia, resembling perithecia (Pl. VI, fig. 2), and is distinct from the species with large brownish sclerotia which has a fertile stage in the genus *Corticium*. *R. destruens* Tass. is also a distinct and separate species, its parasitism on the potato and on lucerne being merely one phase of its activities, while *R. Napi*, with its spore form, is a totally different organism.

The species of *Rhizoctonia* which are known in India are therefore as follows :—

(1) *R. Napi* West. Sclerotia large irregular bodies about 3-12 mm. broad, black on outside, flesh coloured on interior. This species should be removed from the genus *Rhizoctonia*, as it appears to be merely a synonym for *Botrytis*.

(2) *R. destruens* Tass. Sclerotia roughly spherical about 1-2 mm. in diameter, brown on outside, white within.

(3) *R. Solani* Kühn. Sclerotia small black bodies resembling perithecia of an ascomycete. *R. Medicaginis* D. C. is almost certainly the same fungus.

(4) *Rhizoctonia* sp. This form has *Corticium vagum* as its perfect stage, its parasitism in India has been described in a previous communication.[1] The sclerotia are irregular structures 2-5 mm. in diameters dark brown colour both on exterior and within (cf.—*R. destruens*), the mycelium when old becomes of a reddish brown

[1] Shaw, F. J. F. *loc. cit.*

colour. This last form, which in India is parasitic upon groundnut and cowpea, and which bears the very closest resemblance to the *Hypochnus* described by Stevens and Hall[1] as parasitic upon quince, appears to be that which Rolfs, Güssow, Pethybridge [2] have identified with *R. Solani* Kühn; we have given reasons elsewhere for differing from this identification and indeed suggested that it might be *R. destruens* Tass., a supposition now obviously incorrect.

The following is a list of the principal host plants of *Rhizoctonia* in India :—

R. Solani Kühn.	*R. destruens* Tass.	*R. Napi* West	*Corticium vagum* B. & C.
on	on	on	on
Alysicarpus	*Arachis hypogaea*	*Amaranthus tristis*	*Arachis hypogaea*
Arachis hypogaea	*Amorphophallus campanulatus*	*Argemone mexicana*	*Solanum tuberosum*
Carica papaya	*Delphinium*	*Avena sativa*	*Trichosanthes cucumerina*
Citrullus vulgaris	*Dianthus*	*Beta bengalensis*	*Vigna Catiang*
Corchorus capsularis	*Medicago sativa*	*Brassica campestris* var *glauca*	
Crotalaria juncea	*Piper betle*	*Calamintha*	
Cucurbita maxima	*Solanum tuberosum*	*Cannabis sativa*	
Dolichos biflorus		*Chenopodium album*	
Dolichos Lablab		*Cicer arietinum*	
Gossypium		*Cnicus arvensis*	
Hibiscus cannabinus		*Fumaria parviflora*	
Lycopersicum esculentum		*Hordeum vulgare*	
Medicago sativa		*Lathyrus sativus*	
Morus alba		*Lens esculenta*	
Nicotiana Tabacum		*Leucas*	
Phaseolus lunatus		*Linum usitatissimum*	
Phaseolus Mungo var *radiatus*		*Medicago lupulina*	
Sesamum indicum		*Pisum sativum*	
Solanum Melongena		*Scoparia dulcis*	
Solanum tuberosum		*Triticum vulgare*	
Vigna Catiang		*Vicia hirsuta*	

Agricultural Research Institute, Pusa,
March, 1915.

[1] Stevens and Hall. "Hypochnose of Pomaceous Fruits." *Ann. Mycol.* VII, 1909.
[2] Rolfs, Güssow, Pethybridge. *loc. cit.*

DESCRIPTION OF PLATES.

PLATE I.

Fig. 1. Gram plants infected with *R. Napi* West. The infected portion of the plant is light in colour, a growth of mycelium is visible on portions of pods and stem marked " a ".

" 2. Mustard plants infected with *R. Napi* West. One plant has collapsed, the white fluffy growth of mycelium on stems and leaves is clearly visible. Infected portions, marked " a " show white mycelium.

PLATE II.

Fig. 1. *Cannabis sativa* infected with *R. Napi* West., infected portion marked " a " shows white mycelium.

" 2. Section of sclerotium of *R. Napi* West.

" 3. The same showing the outer layer of thick-walled blackish cells.

PLATE III.

Fig. 1. *Delphinium* infected with *R. destruens* Tass. The plant on the right has collapsed at point of infection; the manner in which the mycelium forms white strands both on the soil and on the plants is clearly shown in this and the next photo. It is indicated by letter " a ".

" 2. *Piper betle* infected with *R. destruens* Tass. Note the mycelium (" a ") and sclerotia spreading on the soil.

PLATE IV.

Fig. 1. Corms of suran infected with *R. destruens* Tass.—White growth of fungus (" a ") is easily visible.

" 2. Potato tuber covered with growth of *R. destruens* Tass.

" 3. Potato stem covered with growth of *R. destruens*. Sclerotia are very numerous in both these photos of diseased potato.

PLATE V.

Fig. 1. Hypha of *R. Napi* West. × 1000.
„ 2. Fertile hypha with spores—*R. Napi*. × 250.
„ 3. Conidiophore and conidia—*R. Napi*. × 1000.
„ 4. Fertile hypha in organic connection with hypha of *R. Napi* West. × 250.
„ 5. Section stem of *Delphinium* infected with *R. destruens* Tass. × 375.

PLATE VI.

Fig. 1. Culture of *R. destruens* Tass. from betel vine.
„ 2. „ „ *R. Solani* Kühn from potato.
„ 3. „ „ *R. Napi* West from mustard.
„ 4. „ „ Sclerotial stage of *Corticium vagum* B. & C. from cowpea.

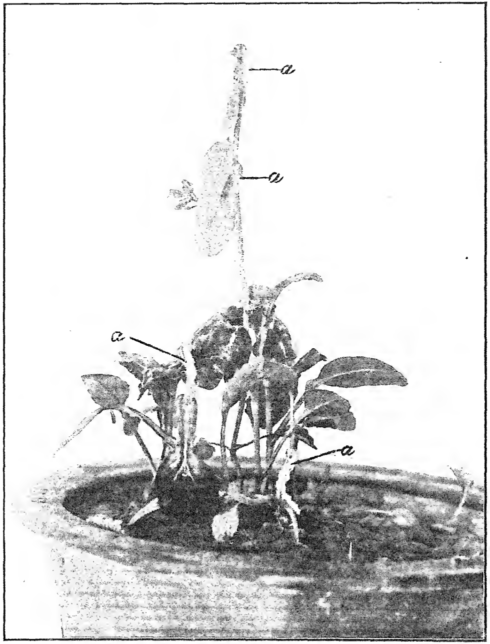


Fig. 1.

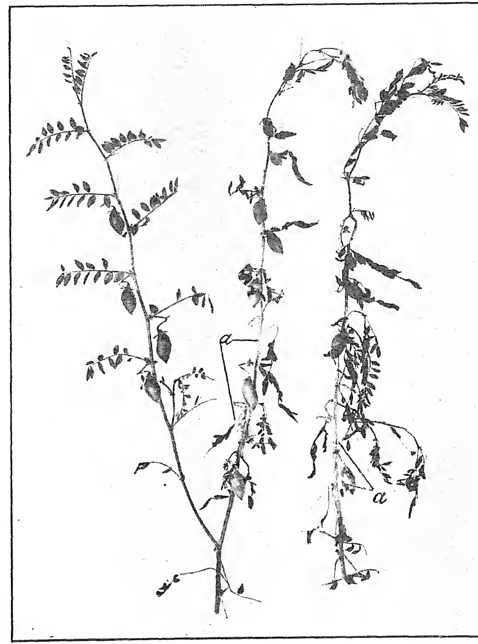


Fig. 2.

Plate II.

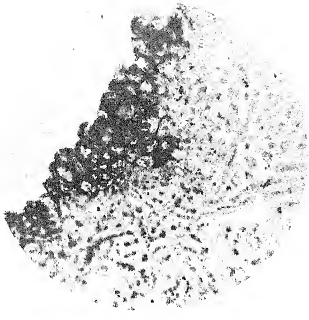


Fig. 2.

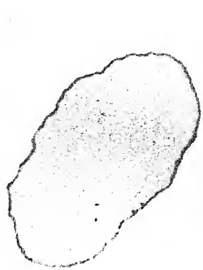


Fig. 3.

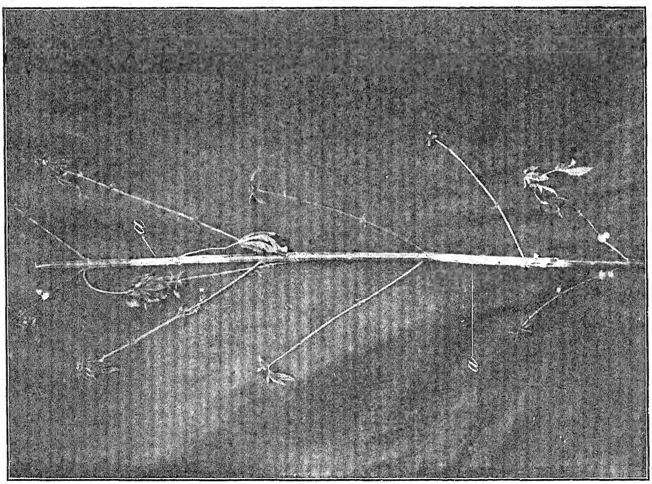
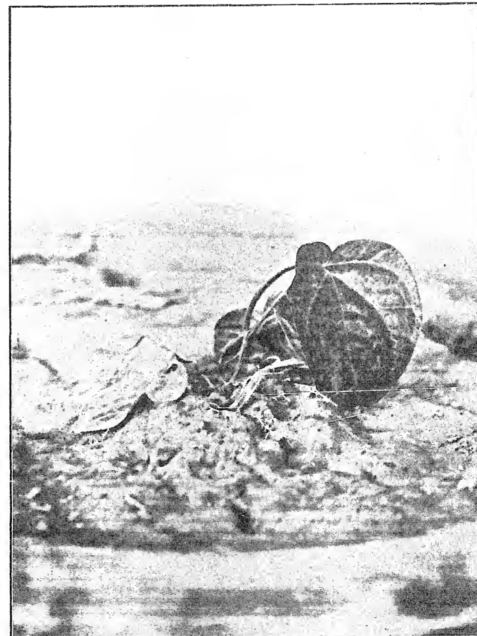


Fig. 1.

Fig. 1.



Fig, 2.

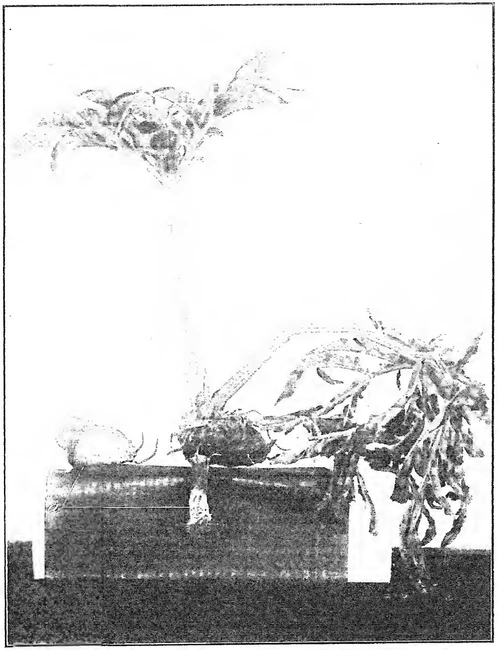


Fig. 1

Fig. 3

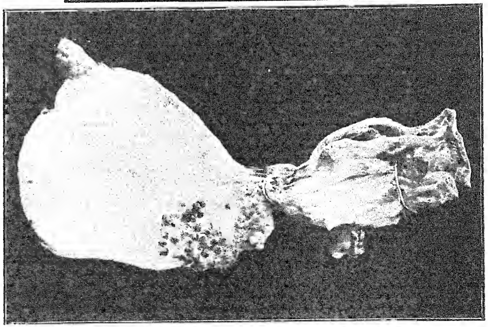
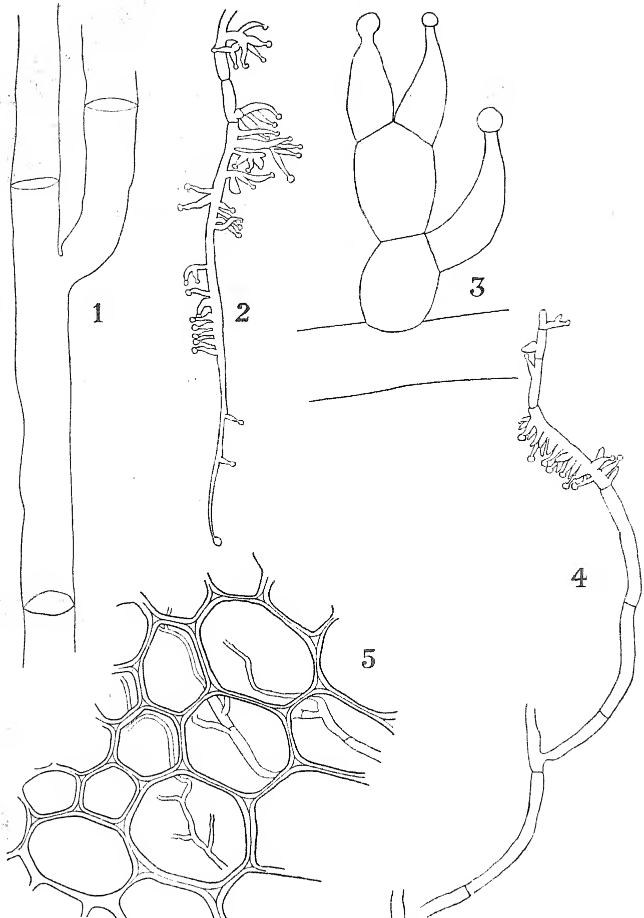


Fig. 2

PLATE V.



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EXPERIMENTS ON THE PHYSIOLOGY OF INDIGO-YIELDING GLUCOSIDES

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AGRICULTURAL RESEARCH INSTITUTE, PUSA

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PREFACE.

The following investigations were carried out whilst I was Botanist to the Bihar Planters' Association at Sirsiah Research Station. When this station was closed down in May, 1913, I hoped that I might be able to continue this work but this is found now to be very improbable. Since definite information on certain points has been obtained, the publication of the results may be of value in view of the fact that very little is known of the biology of indican in particular and glucosides in general.

I wish to take this opportunity of thanking Mr. Bergtheil, late Director of the Sirsiah Research Station, for the help and advice that he gave me throughout the work. I wish to thank also Mr. Harrison, Government Agricultural Chemist, for allowing me to finish off several experiments in his laboratory at Coimbatore.

Coimbatore,

8th March, 1915.

F. R. PARNELL.

EXPERIMENTS ON THE PHYSIOLOGY OF INDIGO-YIELDING GLUCOSIDES.

BY

F. R. PARNELL, B.A.,

Government Economic Botanist, Madras.

Indigo-yielding Glucosides.

Occurrence.

An indigo-yielding glucoside occurs in a number of plants representing widely separated natural orders and including trees, woody shrubs, small herbaceous plants and epiphytic orchids. As far as can be seen these plants do not possess in common any special character from which one can judge the biological significance of the glucoside.

Localization, macroscopic.

The localization of the glucoside in the plant is found to vary considerably in different species. Leake[1] examined a number of species in detail and summarized previous work, mainly of Molisch and Beijerinck, on this subject.

In *Polygonum tinctorium*, Ait., the glucoside is confined to the leaf lamina, Leake,[1] Molisch.[2]

In *Indigofera spp.* it is practically confined to the leaf and youngest parts of the stem though a small amount, varying in the different species, occurs in some of the reproductive organs, Leake.[1]

In *Isatis tinctoria*, L., Molisch[2] and Beijerinck[3] have shown it to occur in parts of the young roots in addition to the aerial vegetative organs.

In *Phajus spp.* and *Calanthe spp.* Molisch[2] finds it in the flower and roots in addition to the aerial vegetative organs.

Wrightia tinctoria, Br., is described by Roxburgh[4] as containing indigo in the leaf. In the course of the present work it was found also in the seed in considerable quantity, in the young roots throughout and in the outer cortex of the old roots. It is absent from the laticiferous vessels.

[1] Leake, H. M. *Annals of Botany*, Vol. XIX, No. LXXIV, April, 1905, p. 297.
[2] Molisch, H. *Sitzb. der Kais. Akad. d. Wiss. in Wien.*, Bd. CII, Abt. 1, 1893, p. 269.
[3] Beijerinck, M. W. *Proc. K. Akad. Wetensch. Amsterdam*, Bd. II, 1900, p. 495.
[4] Roxburgh, W. *Flora indica*, 1874, p. 585.

Wrightia tomentosa, R. & S., was found to contain none in the aerial organs but considerable quantities in the seed and roots as in *Wrightia tinctoria.*

Thus the localization of the glucoside in the plant is not suggestive of any special function common to all the plants in which it occurs; on the other hand, the important differences shown rather raise doubts as to the existence of a common function.

Localization, microscopic.

With regard to the localization inside the cell Molisch[1] considers that some special relation exists between the indican and chloroplasts and seeks to prove this by showing that, when the leaf is treated with the vapour of alcohol or ammonia, indigotin is deposited in the cell in close contact with the chloroplasts. Leake[2] shows that this is not the case when an acid persulphate fixing solution is used. Leake's solution is capable of depositing indigotin wherever it comes into contact with indican. In Molisch's method partial asphyxiation allows the indican and enzyme to interact with production of indoxyl and glucose, the former then being oxidized to indigotin either spontaneously by oxygen in solution in the cell-sap or through the agency of an enzyme. On examination it was found that an oxidase or peroxidase, or both, occurs in the glucoside-bearing parts of all the plants examined, *viz.*:—*I. arrecta, I. sumatrana, W. tinctoria, W. tomentosa, Crotalaria incana* and *Phajus sp.* It is obvious that if oxidation is brought about by this enzyme the indigotin will be deposited in close contact with the enzyme irrespective of where the original indican was localized. Even if no enzyme is concerned in the oxidation, the localization of the glucoside splitting enzyme and any possible variation in oxygen concentration in different parts of the cell would largely control the point of deposition of indigotin. Molisch's results therefore cannot be accepted as demonstrating any connection between the glucoside and chloroplasts.

Nature of Glucoside.

Schunck[3] was the first to show that the indigo-producing substance of *Isatis tinctoria* and *Polygonum tinctorium* is of the nature of a glucoside, which he named indican, capable of yielding indigotin and a sugar on hydrolysis.

Hazewinkel[4] showed that indican obtained from *Indigofera leptostachya* (=*I. arrecta*, Hochst.) is a compound of indoxyl and dextrose. This was confirmed by Perkin and Bloxam[5] who prepared large quantities of pure

[1] Molisch, H. *Ber. d. Deutsch. Bot. Gesell.* Bd. XVII, 1899, p. 228.
[2] Leake, H. M. *Annals of Botany*, Vol. XIX, No. LXXIV, April—1905, p. 297.
[3] Schunck, E. *Phil. Mag.* (4) Vol. X, 1855, p. 74, and Vol. XV, 1858, p. 127.
[4] Hazewinkel, J. J. *Proc. K. Akad. Wetensch. Amsterdam*, Bd. II, 1900, p. 512.
[5] Perkin, A. G., and Bloxam, W. P. *Jl. Chem. Soc. Trans.* Vol. XCI, 1907, p. 1715.

indican and made a careful study of its properties. They also showed that the glucoside of *I. sumatrana*, Gaert., is identical with that from *I. arrecta*.

Beijerinck [1] showed that the glucoside of *Isatis tinctoria* differs from indican in that it is decomposed by even feebly alkaline solutions whereas indican is stable in concentrated alkaline solutions.

In the course of the present work it was noticed that the glucoside of *Wrightia tinctoria* was hydrolised by acid more slowly than was indican from *I. arrecta* under similar conditions. A rough experiment designed to prove this quantitatively was carried out and the results are given in Table I. In each case to 250 c.c. of plant extract at 31°C was added 3 c.c. of strong hydrochloric acid and 3 c.c. of 10 per cent. ammonium persulphate solution After definite times the indigo precipitated was filtered off and estimated with standard permanganate solution.

TABLE I.

Acid Hydrolysis of Glucosides of I. arrecta *and* W. tinctoria.

TIME	INDIGOTIN PRODUCED = PERMANGANATE C.C.		PERCENT HYDROLISED	
	Indigo	Wrightia	Indigo	Wrightia
½ hour	3·85	3·15	67·5	36·2
do.	3·85	lost	67·5	...
1 hour	4·3	3·75	75·5	43·1
do.	4·3	3·85	75·5	44·3
4½ hours	5·7	8·7	100	100
do.	5·7	8·65	100	100

A better idea of the comparative rates of hydrolysis would have been obtained if the plant extracts had been more nearly of equal content, yet the results undoubtedly show that the *Indigofera* glucoside is more readily hydrolised by acid than is that of *Wrightia*.

A more careful experiment for comparing the action of the respective enzymes was carried out with the result shown in Table II. Here the extracts were made approximately of equal content after a preliminary estimation. In each case the enzyme powder was made by extracting the fresh leaf with alcohol of about 90 per cent. till yellowish, drying, grinding, and passing through a fine gauze sieve. It may be noted here that *Wrightia* enzyme will stand much less alcohol treatment than that of *Indigofera*, and it is necessary to get the whole extraction done in about one hour for the powder to be very active. *I. sumatrana* was used in this experiment.

[1] Beijerinck, M. W. *Proc. K. Akad. Wetensch. Amsterdam*, Bd. III, 1900, p. 101.

In each case 400 c.c. of plant extract was used, to this was added five drops of chloroform, 0·5 gm. *Indigofera* enzyme or 0·75 gm. *Wrightia* enzyme and the whole put on a shaking machine for the time stated. To stop the action 10 c.c. of strong ammonia was added and the whole shaken with air for some time to oxidize any indoxyl present. After boiling and filtering the remaining glucoside was estimated by the indirubin method.

TABLE II.

Interaction of Enzymes and Glucosides of I. sumatrana *and* W. tinctoria.

No.	Enzyme	Time	Per cent. hydrolised		Remarks
			Indigo Extract	Wrightia Extract	
1	Indigo	4 hrs.	83·0	34·1	Shaken together.
2	do.	do.	74·6	37·4	
3	do.	16 hrs.	100·0	34·1	
4	do	do.	100·0	29·0	
5	Wrightia	4 hrs.	33·9	86·9	do.
6	do.	do.	38·1	83·6	
7	do.	16 hrs.	67·0	100·0	
8	do.	do.	72·0	100·0	

N. B.—Relative concentrations of extract: *Indigofera* 118, *Wrightia* 107.

It will be seen from the Table that *Indigofera* enzyme acts much more strongly on *Indigofera* extract than on *Wrightia* and *vice versâ*. There is not the least doubt that both the glucosides and enzymes, although very similar, are not identical.

PHYSIOLOGICAL CONSIDERATIONS.

Wrightia Seed and Seedlings.

Both *W. tinctoria* and *W. tomentosa*, as noted above, contain an indigo-producing glucoside in the seed. The following experiments were designed to show what effect germination and growth would have on the quantity of glucoside present.

The seeds are large and easy to handle, *W. tinctoria* being about the size and shape of an oat grain, *W. tomentosa* being rather smaller. An even batch of good sound seed was picked out and sown in well washed nitrogen-free sand in porcelain pots. These were watered throughout with nitrogen-free distilled water and lots were taken for analysis at intervals throughout germination and growth.

It was found impossible to get full germination so that the actual weight of seed giving each lot of plants could not be determined. For this reason the results are expressed in terms of numbers of seedlings. Equal numbers do not represent absolutely equal weights of seed and to estimate the experimental error thus involved weighments were made of several random lots of seed from each batch, in number the same as the lots of plants analysed. These are given at the foot of each table.

In all cases the glucoside was estimated by extraction with boiling water[1] and precipitation of indirubin by boiling with hydrochloric acid and isatin in an atmosphere of carbon dioxide. In Tables III and V the indirubin was measured tintometrically in alcoholic solution ; in Table IV it was weighed.

TABLE III.

Wrightia tinctoria *Seed germinated and grown on distilled water.*

No.	Number seedlings	Age in days	Indirubin per 16 plants	Average relative amounts	REMARKS
1 a	16	2	0·0097	1	Seed germinating, radicle ¼″—½″ long.
b	do.	do.	0·0093		
2 a	do.	4	0·0123	1·30	Radicle with root hairs, cotyledons about to open.
3 a	do.	7	0·0143	1·48	Cotyledons well open.
b	do.	do.	0 0139		
4 a	do.	11	0·0161	1·70	Plumule elongated.
5 a	do.	15	0·0175	1·87	1st. pr. real leaves.
b	do.	do.	0·0180		
6 a	do.	25	0·0233	2·55	2nd. do.
b	do.	do.	0·0252		
7 a	do.	38	0·0269	2·95	3rd. do.
b	do.	do.	0·0292		
8 a	16	53	0·0260	2·70	4th. do.
b	8	do.	0·0252		Slightly yellowish.
9 a	10	77	0·0177	1·74	do. very yellow, nitrogen starved.
b	do.	do.	0·0153		
10 a	do.	99	0·0248	2·50	Nitrate solution added after No. 9 analysed and plants healthy looking again.
b	do.	do.	0·0228		

Seed weight, 16=0·782, 0·905, 0·833, 0·750, Average 0·817.

[1] Very careful extraction is necessary to ensure removal of all the glucoside from the seed. The procedure was to boil 3—4 mins., filter through fine linen, grind in mortar, boil and filter again squeezing the pulp in linen, boil and filter once more. The milky extract was cleared by twice washing with ether and then boiling with a trace of ammonia and filtering through paper.

TABLE IV.

Wrightia tinctoria *Seed germinated and grown on distilled water.*

No.	Number seedlings	Age in days	Weight when analysed	Indirubin per 100	Average relative amounts	REMARKS
A 1 a	100	*Nil.*	4·35	0·063	1	Dry seed.
b	do.	do.	4·05	0·061		
,, 2 a	do.	4	8·23	0·0685	1·19	Germinated, radicle ½".
b	do.	do.	8·65	0·079		
,, 3 a	do.	8	10·65	0·079	1·29	Radicle 1" with root hairs.
b	do.	do.	10·63	0·0806		
,, 4 a	112	12	30·30	0·093	1·51	Cotyledons well open.
b	do.	do.	32·70	0·095		
B 1 a	100	*Nil.*	4·41	0·071	1	Dry seed.
b	do.	do.	4·18	0·074		
,, 2 a	102	22	37·00	0·094	1·27	1st. pr. real leaves.
b	do.	do.	40·60	0·0905		
,, 3 a	77	31	42·00	0·184	2·56	3rd. do.
b	do.	do.	42·50	0·187		

Seed weight A 650=27·62, Average 100=4·25.
B 100=4·39, 4·64, 4·51, 4·65, Average=4·55.

N.B.—A and B represent seed from different sources.

TABLE V.

Wrightia tomentosa *Seed germinated and grown on distilled water.*

No.	Number seedlings	Age in days	Indirubin per 16 plants	Average relative amounts	REMARKS
1 a	16	*Nil.*	0·00406	1	Dry seed.
b	do.	do.	0·00438		
2 a	do.	2	0·00450	1·02	Germinating, radicle ½" long.
b	do.	do.	0·00410		
3 a	do.	10	0·00370	0·92	Cotyledons well open.
b	do.	do.	0·00405		
4 a	do.	23	0·00483	1·10	1st. pr. real leaves.
b	do.	do.	0·00447		
5 a	do.	35	0·00439	1·13	2nd. do.
b	do.	do.	0·00517		
6 a	do.	47	0·00392	0·93	3rd. do.

Seed weight, 16=0·381, 0·387, 0·414, 0·382, Average=0·391.

It will be seen from Table III that in *W. tinctoria* the amount of glucoside increases as the seedling develops until a maximum is reached in No. 7 at 38 days. After this the seedlings stop growing, begin to get yellow and show obvious signs of nitrogen starvation and the amount decreases. Nitrate solution was supplied to the seedlings at this stage and they rapidly recovered and the glucoside content increased. Table IV confirms these results on a larger scale, so far as the gradual increase of glucoside is concerned, but was not carried far enough to show the ultimate decrease. It appears that in the ordinary course of germination the glucoside of the seed does not act as a nitrogenous reserve for use in building up new tissue but actually increases at the expense of other nitrogenous matter. When, however, nitrogen starvation begins to be felt the glucoside begins to disappear, apparently being drawn on as a source of nitrogen. It is obviously not very readily available for this purpose, however, since Nos. 9 (*a*) and (*b*) of Table III were almost on the point of death from lack of nitrogen and yet contained a good deal of glucoside. It may be noted here that the glucoside nitrogen represents only slightly more than 1 per cent. of the total nitrogen of the seed.

Table V shows the very different behaviour of *W. tomentosa* under similar conditions. It is evident that the amount of glucoside remains fairly constant for the period shown. There is no large increase comparable with that of *W. tinctoria*. This is no doubt connected with the fact that in *W. tomentosa* the glucoside is confined to the root system whereas in *W. tinctoria* it is present also in the leaf and young stem. The meaning of these differences is not clear on the supposition that the function of the glucoside is the same for both species.

Owing to lack of seed the experiment could not be repeated on a larger scale and stages showing nitrogen starvation could not be included.

Consumption of Glucoside by Developing Cuttings.

Polygonum tinctorium and *Strobilanthes flaccidifolius* were chosen as indigo-yielding plants which very readily strike root when parts of the shoot are placed in water. It was possible, by making duplicate lots of cuttings, analysing one immediately and the other after growth for some time on nitrogen-free water, to detect any consumption of glucoside taking place under these conditions. Cuttings of various sorts were tried in this manner, *e.g.*, growing points with a few leaves, axillary shoots with node of origin with and without subtending leaf, single leaves with node of origin and axillary bud, etc. In all cases a number of similar cuttings was made and divided into two lots *a* and *b*

by taking pairs as nearly alike as possible ; *a* was analysed directly, *b* struck and analysed after growing for some time on nitrogen-free distilled water. The cuttings rooted freely and showed considerable increase in weight.

Tables VI and VII give the results obtained and show in every case a reduction in the amount of glucoside after growth.

Table VI.

Polygonum tinctorium *Cuttings.*

No.	No. of cut-tings	Original weight	Days on water	Final weight	Per cent wt. in-crease	Indigotin percentage	Per cent. diffce.	Remarks
1 a	39	7·30	...	......	...	0·256	—59	Axillary shoots with node of origin.
b	37	7·00	22	12·65	80·9	0·104		
2 a	36	8·15	...	......	...	0·324	—77	do.
b	35	7·74	20	13·67	76·4	0·075		
3 a	25	7·65	.	......	...	0·266	—0·7	do.
b	25	7·21	22	12·0	66·4	0·264		
4 a	22	10·20	...	......	...	0·310	—78	do.
b	22	10·60	22	18·4	73·8	0·069		
5 a	38	11·22	...	......	...	0·459	—14	Same batch.
	28	8·22	10	12·05	47	0·395		
6 a	36	15·10	...	......	...	0·307	—13	
b	34	15·40	10	20·67	34	0·267		
7 a	50	10·87	...	......	...	0·336	—23·5	Same batch.
b	47	9·90	24	16·2	64	0·257		
8 a	30	10·82	...	......	...	0·362	—27	
b	27	9·30	24	15·4	66	0·264		
9 a	18	10·80	...	......	..	0·270	— 9·3	
b	17	9·90	18	15·6	58	0·245		

N.B.—1-4 by indigotin method,
5-9 by indirubin method,
both calculated as indigotin % of original cuttings.

TABLE VII.

Strobilanthes flaccidifolius *Cuttings.*

No.		No. of cut-tings	Origi-nal weight	Days on water	Final weight	Per cent wt. in-crease	Indigotin per cent.	Per cent. diffce.	Remarks
1	a	12	20·4	...	...	...	0·890	−6·2	Axillary shoot with half node.
	b	12	19·5	6	22·9	17·5	0·835		
2	a	26	32·7	...	...	...	0·87	−5·7	Young axilly. shoot with subtg. leaf.
	b	25	30·6	30	38·5	25·8	0·82		
3	a	7	6·0	...	...	...	1·26	−17·5	Younger do.
	b	7	6·1	30	7·95	30·4	1·04		
4	a	6	6·3	...	...	...	1·42	−34·5	Stem apex with few young leaves.
		6	7·4	58	11·8	59·5	0·93		

N.B.—Indirubin method, calculated as indigotin % of original cuttings.

There is very considerable variation in the amount of reduction shown by different lots. In Table VI Nos. 1—4 were similar cuttings receiving the same treatment and giving a fairly uniform increase in weight; with the exception of No. 3, which appears to have gone wrong in some way, the glucoside reduction is fairly uniform. Nos. 5 and 6 are similarly uniform; of Nos. 7—9, No. 9, which is rather low, was composed of larger cuttings with a lower initial content and showed less increase in weight owing to its shorter period of growth.

In Table VII the loss of glucoside varies with the increase in weight and initial content. Material was not available for determining the relative importance of the latter factor in its relation to the reduction of glucoside nor to see whether initial total nitrogen content was of importance in this respect.

It is quite certain from the above results that cuttings containing the glucoside make use of it during their development when nitrogen is not supplied from outside. Analyses of the water on which the cuttings were grown showed no trace of glucoside so that there was no loss by diffusion through the stalks or roots.

Relation between Glucoside Content of Leaf and Stage of Development.

Indigofera arrecta and *Wrightia tinctoria* have been examined in this connection and in both cases the glucoside is found throughout the whole development of the leaf from its rudimentary condition at the growing point to the fully mature state and even after leaf-fall.

Table VIII shows the quantitative variation for different stages of *I. arrecta*. A and B represent two different plants; in series A the duplicates *a* and *b* were chosen from the same parts of the plant and as nearly alike as possible. It will be seen that the actual amount of indican per leaflet increases throughout with increase of size. The percentage, however, is not constant since the content and weight do not increase proportionately. Series B shows that during the very early stages of growth the percentage increases to a maximum and then falls regularly to a minimum at maturity. Series A shows only the decrease since it does not include sufficiently early stages to show the initial rise.

TABLE VIII.

Indigofera arrecta *developing Leaf.*

No.	Number of leaflets analysed	Weight 100 leaflets	Permang. N/100 c.c. per 100 leaflets	Indigotin percentage
A 1 a	121	0·70	8·9	0·88
,, b	114	0·67	8·6	0·89
2 a	117	0·91	10·9	0·83
,, b	109	0·87	10·1	0·82
3 a	116	1·35	12·6	0·65
,, b	108	1·23	12·2	0·69
4 a	115	2·11	19·5	0·64
,, b	126	2·16	19·3	0·62
B 1	393	0·26	3·1	0·84
2	273	0·36	4·5	0·89
3	278	0·50	6·6	0·94
4	245	0·71	8·0	0·80
5	209	0·84	9·0	0·76
6	191	1·12	10·9	0·67
7	210	1·54	13·6	0·62
8	211	1·89	13·7	0·51

N.B.—Indigotin precipitated, sulphonated and titrated with permanganate.

Table IX shows similar relations for *W. tinctoria* with the exception of the initial rise which possibly occurs at a stage earlier than is included. It might appear from Nos. 4 and 5 that some loss of glucoside from the leaf occurs in the last stages. There is little doubt, however, that this does not represent actual fact; No. 4 comprised leaves of a slightly later period of growth than No. 5 and they would have become distinctly larger than the latter at maturity since, for a time, as the growing season advances, the size of the mature leaf increases. Thus it is more than probable that No. 4 leaves,

at the degree of maturity represented by No. 5, would have been appreciably larger than the latter and the glucoside content would have been correspondingly greater.

In the second half of Table IX, *a* represents a lot obtained by taking for analysis one leaf from each of a number of pairs of just mature leaves, *b* comprising the opposite leaves which were left on the plant for one month and then analysed. In each case the *b's*, at the time of analysis, were just beginning to shed, several leaves having actually fallen and the others falling at a touch. It is obvious that the glucoside content is unaltered by the aging of a mature leaf, moreover there is no removal before leaf-fall.

TABLE IX.

Wrightia tinctoria *developing Leaf.*

No.	Number of leaves analysed	Weight 100 leaves	Indigotin per 100 leaves	Indigotin percentage
1	231	4·9	0·0374	0·76
2	100	16·4	0·109	0·66
3	30	67·5	0·263	0·39
4	14	158	0·521	0·33
5	16	173	0·388	0·22
I a	17	172	0·371	0·21
b	16	178	0·377	0·21
II a	17	201	0·388	0·19
b	17	207	0·373	0·18

N.B.—Indirubin precipitated and calculated as indigotin content.

Table X shows exactly the same for *I. arrecta*. In this case before shedding the leaf turns yellow; *b* represents such yellow leaf shaken from the plant in the early morning, *a* represents mature green leaf from the same plant taken on the same day. The indican content is obviously the same for both, showing that no withdrawal takes place before leaf-fall. The total nitrogen content as given by Kjeldahl analysis shows that a very large proportion of other nitrogenous matter has been withdrawn. Similarly whilst the green leaf contained large quantities of starch there was none in the yellow. The fact that the indican remains intact, whilst all the starch and a large proportion of the total nitrogenous matter are removed before shedding, suggests that indican is of little importance as a nutrient substance.

Since this was written Howard and Howard have stated (*Second Report on the Improvement of Indigo in Bihar*, pages 4 and 5) that indican acts as a reserve which is utilized by the plant at flowering and times of starvation. In view of the results here published the author is unable to accept these conclusions. [F. R. P.]

TABLE X.

Indigofera arrecta *falling Leaf.*

No.	Leaf	Indigotin per cent.	Equal to Nitrogen per cent.	Total Nitrogen per cent.
1 a	Green	0·45	......	......
b	Yellow	0·48	......	......
2 a	Green	0·44	0·047	0·97
b	Yellow	0·47	0·050	0·39
3 a	Green	0·48	0 051	0·97
b	Yellow	0·45	0·048	0·33

N. B.—Indigotin precipitated, sulphonated and titrated with permanganate.

In this connection it may be remarked that the enzymic activity is less in the yellowed leaf than in the green. It was noticed that when yellow and green leaf of equal indican content were placed to steep in water under similar conditions there was considerably less action in the case of the yellow than the green.

For a quantitative estimation of the differences some enzymically active leaf powder was made from yellow and green leaf respectively of the same plant by extraction with alcohol, under similar conditions, till colourless, drying and powdering. Equal weights, 0·4 gm., of these powders were added to 250 c.c. aliquots of plant extract at 35° C and allowed to act for 25 mins. during which time they were well shaken. After addition of ammonia and thorough shaking and boiling they were filtered and the remaining indican estimated together with a control aliquot of the plant extract. It was found that of the original indican 16·4 per cent. had been hydrolised by the green leaf enzyme powder as against 11·2 per cent. by the yellow. Thus a considerable loss of activity is shown after yellowing. The reason for this is uncertain though it is possible that part of the enzyme is removed along with the other nitrogenous material.

Connection between Light and Glucoside Production.

That indican production is not dependent on light was shown very easily by covering the stump of a cut down plant of *Indigofera arrecta* with a light-tight kerosene tin. Shoots arose from the stump and after two or three weeks these were analysed. They were typical etiolated shoots, devoid of chlorophyll, with very small leaves and long slender succulent stem. Indican was found

in all parts. Their indican content was compared with that of normal shoots of the same age, a number of whole shoots of each being cut from the stumps and analysed.

Normal ...	...	0·71 per cent. indigotin.	
Etiolated ...	...	0·28 do.	do.

Strict comparison is impossible owing to the different nature of the two—thus the very succulent nature of the etiolated shoots no doubt accounts partly for the low content. It is obvious that indican in considerable quantity can be produced in the dark. Since an old stump without leaves contains no indican, it could not be a matter of translocation of already existing indican.

Molisch[1] obtained the same result with etiolated shoots of *Indigofera anil*, *Marsdenia tinctoria* and *Isatis tinctoria* but was not certain that the glucoside was not translocated from normal leafy shoots which were present on the same plant in each case. On the other hand, he found that *Isatis tinctoria* seedlings produce no indican when raised in the dark and seedlings containing indican lose the whole of it when put into darkness for two or three weeks. He gives no account of the state of the seedlings after several weeks of darkness and it is impossible, for this reason, to draw definite conclusions from his results. If the seedlings dropped nearly all their leaves, which commonly happens with plants put in darkness, the indican contained in them would be lost also. The fact that they contained no indican at the end of the time would then mean that the leaves produced in darkness under those conditions formed no indican. There would be no evidence that already existing indican had been used up.

This would be in accord with the fact that seedlings raised in the dark produce no indican. On the other hand, he shows that indican is produced in etiolated shoots arising from a large plant of *Isatis*. This seeming anomaly would admit of the simple explanation that in a small seedling growing in darkness a very serious deficit of carbohydrates is bound to occur, whereas a larger plant or stump will contain sufficient carbohydrate, stored in its tissues, to carry on for a long time in darkness. Since the glucoside is directly dependent on some carbohydrate for its construction, it is more than probable that simple lack of carbohydrate is responsible for its non-production in small seedlings grown or raised in darkness.

Molisch[2] also gives results showing the effect on the indican content of keeping plants of *Indigofera sp.* in the dark for 24 hours. Batches of six

[1] Molisch, H. *Sitzb. der Kais. Akad. d. Wiss. in Wien.* Bd. CVII, Abt. I, 1898, p. 747.
[2] *Loc. cit.*

plants were analysed after remaining in the open and being enclosed for 24 hours in a light-tight covering respectively. In each case the darkened plants showed a lower indican content than the normal plants left in the open, the difference varying from 6·8—17 per cent. of the normal content.

The following results obtained in this line of work differ very considerably from those of Molisch. The turgidity of the leaflet varies considerably according to the atmospheric conditions at different times during the day. This alone produces variation in the indican content when the latter is calculated as percentage of fresh weight. For this reason the results have been given also as indigotin per 100 leaflets. The error due to variation in size of the leaflet is made comparatively small by the large number taken.

Table XI gives the indican content at sunrise and sunset respectively of indigo leaves. Nos. 1 and 2 represent single plants of *I. arrecta*; No. 3 represents a batch of twelve plants of *I. sumatrana* from each of which four leaves were picked for each of the four lots included. Normal mature leaves were taken in each case and the leaflets only were analysed by the indirubin method.

TABLE XI.

Indigofera spp., *Indican Content after night and day.*

No.	Time of analysis	Number of leaflets	Weight	Weight of 100 leaflets	Indigotin per cent.	Indigotin per 100 leaflets
1 a	Sunrise	273	7·81	2·86	0·491	0·0141
b	Sunset	266	7·02	2·64	0·509	0·0134
2 a	Sunrise	315	6·86	2·18	0·373	0·00813
b	Sunset	324	6·10	1·88	0·422	0·00795
3 a	Sunrise	436	23·28	5·34	0·591	0·0315 }
a′	do.	428	22·04	5·15	0·608	0·0313 }
4 b	Sunset	435	22·44	5·16	0·612	0·0314 }
b′	do.	448	23·07	5·15	0·614	0·0316 }

It is obvious from the figures that there is no appreciable difference in indican content between the two times.

Table XII gives a comparison between the indican content of three batches of *I. sumatrana* taken after *twelve hours daylight* and *thirty-six hours darkness* respectively. Those marked *a* were analysed at sunset after about twelve hours of daylight, those marked *b*, the same plants thirty-six hours later, at sunrise, after being two nights in the open and in darkness under a tent during the intervening day. As before, mature leaves were taken and the leaflets only analysed by the indirubin method.

Table XII.

I. sumatrana *Indican Content.*

(a)—after twelve hours daylight.
(b)—after thirty-six hours darkness.

No.	Number of leaflets	Weight	Weight per 100 leaflets	Indigotin per cent.	Indigotin per 100 leaflets	Average
1 a a′	464 450	16·63 16·26	3·59 3·61	0·533 0·542	0·0191 0·0196	0·0193
b b′	428 442	14·14 14·10	3·36 3·19	0 563 0·558	0 0186 0·0178	0·0182
2 a a′	549 529	19·13 19·06	3·49 3·60	0·580 0·551	0·0202 0·0199	0·0200
b b′	502 533	16·48 18·57	3·28 3·49	0·589 0·572	0·0193 0·0199	0 0196
3 a a′	284 281	11·24 11·23	3·96 4·00	0·629 0·590	0·0249 0·0236	0·0242
b b′	264 260	11·84 11·42	4·49 4·40	0·536 0·585	0·0241 0·0257	0·0249

The figures prove definitely that there is no large alteration in indican content after thirty-six hours of darkness. It is probable that the small variation shown is due to experimental error in sampling and analysis, the whole nature of the experiment making it very difficult to get exact results.

It follows from these results that either indican remains unaltered in the mature leaf, taking no part in normal metabolism, or, if it takes part in metabolism, its rates of production and removal are approximately equal irrespective of whether the plant is in light or darkness.

It is not easy to see why Molisch's results showed a large reduction in indican content in the leaf after twenty-four hours in darkness. He neglected the variation due to differences in turgidity—differences that might amount to a very considerable proportion if not specially guarded against. His plants were enclosed for twenty-four hours in a covering of which he gives no description. It is quite common, when a plant is enclosed with an airtight covering, for the leaves to turn blackish and many of the young shoots to die even after twelve hours under certain conditions. Possibly he was actually measuring the effect on indican content of a pathological condition set up by the conditions of his experiment. It may be noted that the plants of Table XII

above were perfectly healthy looking after their spell of darkness since a period of only twelve hours was spent under a covering and that was large and admitted of ventilation.

Function of Glucoside.

Two suggestions have been put forward of the function of indigo-yielding glucosides, both tentatively and without definite supporting evidence.

Molisch,[1] as a result of his work to which reference has already been made, considers that some definite connection exists between indican production and carbon dioxide assimilation and suggests that indican may represent the first step in the synthesis of proteids from carbohydrates and inorganic nitrogen.

The formation of the glucoside is obviously dependent on the presence of a carbohydrate, but that there is no immediate connection with carbon dioxide assimilation follows from the fact that indican is produced in the etiolated shoots arising from an indigo stump kept in darkness. Moreover the occurrence of the glucoside in the roots only of *Wrightia tomentosa* points to the same conclusion.

With regard to its function in metabolism as the first nitrogenous organic product in the synthesis of proteids it is very unlikely that it is confined to this rôle. Indigo seed, which contains no indican, if supplied with nitrogen-free water, produces seedlings containing indican. This was not carried out under absolutely sterile conditions but no trace of nodule formation could be seen. As shown above, Tables III and IV, the amount of glucoside contained in the seed of *Wrightia tinctoria* increases considerably on germination and growth on nitrogen-free water. It is probable that the glucoside in these cases is produced at the expense of higher organic compounds by catabolic processes.

That the glucoside can be used as a nitrogenous reserve appears evident from the results given in Tables III, VI, and VII which show the reduction in glucoside content produced by the nitrogen starvation of seedlings of *W. tinctoria*, and cuttings of *Polygonum tinctorium* and *Strobilanthes flaccidifolius* respectively.

Whether this is a normal function is open to doubt. If this be the case it appears unlikely that so large an amount of glucoside would remain in seedlings on the point of death from nitrogen starvation—No. 9, Table III. Moreover it has been shown that the whole of the glucoside is thrown away at leaf-fall whereas a large proportion of other nitrogenous matter and all

[1] Molisch, H. *Sitzb. der Kais. Akad. d. Wiss. in Wien.* Bd. CVII, Abt. 1, 1898, p. 747.

the starch is removed from the leaf before it falls. This does not point to the importance of the glucoside as a reserve material.

It seems unlikely that a compound functioning as a reserve, or as a step in normal metabolism, should remain so remarkably uniform in concentration as indican is found to be. Its maximum percentage concentration occurs whilst the leaf is very small. As the leaf develops the actual content of indican increases and reaches a maximum at about maturity. The rate of increase, however, does not keep pace with the growth of the leaf, thus resulting in a gradual decrease in the percentage content. After once attaining a maximum, at the maturity of the leaf, the amount of indican remains unaltered, day and night, throughout its life and even at leaf-fall no alteration can be detected.

It is fairly certain that the seasonal variations in the percentage content of mature leaf of a plant are due to variations in the amount of indican produced during the development of different flushes of leaf. Thus it is common to find that the leaf produced during a rapid flush after rain contains a lower percentage of indican than the already existing older leaf that was produced more slowly.

This is in accordance with the well known fact that rank growth tends to low indigo content and slow growth to high content. Another example of this is seen in the usual effect of heavy nitrogenous manuring of indigo: the amount of green leaf is increased considerably but its percentage content is very much reduced.

Walther[1] suggests that indican is a *prochromogen* and that indoxyl functions as a respiratory chromogen in accordance with Palladin's theory of respiration. He shows that the other requirements of the theory, *viz.*, reducing and oxidizing enzymes, are both present, so that the suggestion is possible but remains to be proved.

It seems that considerable further knowledge on the whole subject is necessary before any conclusions can be drawn as to the function of the glucoside. There is considerable doubt as to whether the function is the same in different species and it is quite certain that the actual glucoside is not the same in all.

Summary.

The following is a summary of the conclusions arrived at as a result of the above investigations :—

1. An indigo-yielding glucoside is present in the root and seed of both *Wrightia tinctoria*, Br. and *W. tomentosa* R. and S. It is absent from the leaves of the latter.

[1] Walther, Oscar. *Ber. d. Deutsch. Bot. Gesell.* Bd XXVII, 1909, p. 106.

2. The glucoside and its enzyme in *W. tinctoria* are distinct from those of *Indigofera arrecta* and *I. sumatrana* although *Wrightia* enzyme has some action on *Indigofera* glucoside and *vice versâ.*

3. *W. tinctoria* seed, when germinated and grown without nitrogen, increases in glucoside content till it becomes about trebled at about forty days. As nitrogen starvation begins to show the amount decreases but is still considerable when the seedlings are on the point of death.

4. *W. tomentosa* seedlings show no appreciable increase of glucoside under the same conditions.

5. When cuttings of *Polygonum tinctorium* and *Strobilanthes flaccidifolius* are grown without nitrogen part of the glucoside disappears, presumably being used up as a nitrogenous reserve.

6. In *W. tinctoria* and *I. arrecta* the maximum percentage content occurs at a very early stage in the development of the leaf. The actual amount in any leaf, however, increases during growth to a maximum at maturity and remains constant till leaf-fall when the whole is present in the fallen leaf.

7. Indican is produced in the dark by etiolated shoots of *I. arrecta.*

8. There is no variation in indican content between night and day in *I. arrecta* and *I. sumatrana.* Moreover no marked effect is produced by keeping plants of *I. sumatrana* in the dark for thirty-six hours.

9. In the light of present knowledge no definite function can be assigned to indigo-yielding glucosides in general or to the glucoside of any special species.

COIMBATORE,

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MEMOIRS OF THE DEPARTMENT OF AGRICULTURE IN INDIA

SOME VARIETIES OF INDIAN GRAM

(*Cicer arietinum*, L.)

BY

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DIEU ET MON DROIT

AGRICULTURAL RESEARCH INSTITUTE, PUSA

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SOME VARIETIES OF INDIAN GRAM.

(*Cicer arietinum*, L.)

BY

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I. INTRODUCTION.

In spite of the fact that gram (*Cicer arietinum, L.*) is an important cold-season food-grain in a large portion of the Indian Empire and also in South Europe, little attention has hitherto been paid to this plant. It is not one of the crops mentioned in Fruwirth's *Die Züchtung der landwirtschaftlichen Kulturpflanzen,* an omission which indicates that this plant has not attracted the attention of plant-breeders.

In India, including the Native States, the area under gram every year is roughly 18,000,000 acres, of which about a quarter is contributed by the Province of Agra. Practically all the cultivation is found in the Indo-Gangetic alluvium and on the adjacent portions of the Central Provinces, Central India, and Rajputana. Watt, in the *Commercial Products of India,* states that a line drawn from Bombay to Patna would approximately divide India into two sections, the northern being the great gram area and the southern that in which gram is a subordinate crop. Much of the gram produced is grown in the form of a mixed crop with wheat or barley. The area and yield in the different Provinces are given in the table below. It will be seen that the average yield in British India is 688 lb. per acre.

TABLE I.

Area and average yield of gram in 1911-12.[1]

Province	Area (in acres)	Yield (irrigated) in lb. per acre	Yield (unirrigated) in lb. per acre
Assam	905	...	...
Bengal	176,700	...	881
Bihar and Orissa	992,100	...	881
Oudh	1,697,097	950	800
Agra	5,175,443		
Punjab	4,099,894	625	534
North-West Frontier Province	174,119	730	449
Sindh	76,439	476	...
Bombay	422,274	1,200	420
Central Provinces	993,113	...	532
Berar	117,221	...	...
Madras	134,900	...	...
Upper Burma	38,905	...	414
Lower Burma	1,377	...	...
Ajmer Merwara	26,176	...	...
Coorg	1,540	...	...
Pergana Manpur (Central India)	678	...	...
Total—British India	14,128,881	Average yield 688 lb. per acre.	
Total—Native States	4,039,929		
GRAND TOTAL	18,168,810		

The grain is an important food for man and cattle while the dried stems and leaves are used as fodder. There is a general idea among the cultivators that a gram crop improves the land, a result probably due to the fact that it is a deep-rooted, leguminous crop which also adds a good deal of organic matter to the soil by the fall of the leaves before it is reaped. The pods and leaves produce an acid secretion, a fact which has been known from the remotest antiquity. Watt[2] states that this secretion is composed of malic and oxalic acids and that it is systematically collected by spreading clean cotton cloths

[1] *Agricultural Statistics of India for the years* 1907-08 to 1911-12, Calcutta, vol. I, 1913, pp. 120 and 387.

[2] Watt, *Commercial Products of India*, 1908, p. 300.

over the growing plants at night and collecting from these the vinegar with which they have become charged. This substance is used both medicinally and in diet.

Most of the gram grown is consumed in India but, of late years, the export trade has increased, particularly from Karachi. The export figures for the last six years are thus stated in the *Review of the Trade of India in 1913-14* :—

	Tons
Average of previous three years	148,563
Export in 1911-12	346,742
Export in 1912-13	144,919
Export in 1913-14	70,000

Taking the year 1912-13 as an example, the export of gram to the whole British Empire reached 879,489 cwt. of which 697,767 were sent to Great Britain. The remainder was principally exported to Ceylon (87,068 cwt.), Straits Settlements (36,822 cwt.), and to Mauritius (41,161 cwt.). A much larger quantity (2,018,895 cwt.) found its way to foreign countries, the principal importers being Germany (1,008,075 cwt.), France (698,049 cwt.), and Belgium (138,870 cwt.). All the large ports were concerned in this trade but the bulk (2,087,888 cwt.) was shipped from Karachi. Bombay (672,686 cwt.) and Calcutta (102,987 cwt.) came next in order while the share of Madras and Burma was small.[1]

The experience obtained at Pusa in the cultivation of gram throws a considerable amount of light on the needs of this crop and on its present distribution in India. As regards soil, the best returns have always been obtained on light, high-lying, well-drained land which is not in very good condition as regards fertility. The time of sowing is also important. The best yields have been realized when the crop has been put in rather late, during the first week in November, by which time the light lands have had time to lose a good deal of their moisture. Any deviation from these conditions, as regards soil and time of sowing, has always led to trouble and loss. Grown on heavy, moisture-retaining plots, such as are most suitable for wheat, gram grows rapidly at first and there is every promise of a high yield. After flowering time, however, it is observed that the plants begin to show signs of wilt and very few pods set seed. The crop seems to wither away in spite of the fact that the soil contains abundance of moisture. Early sowing, even on the light lands which suit

[1] *Annual Statement of the Sea-borne Trade and Navigation of British India with the British Empire and Foreign Countries.* vol. I, 1913, p. 594.

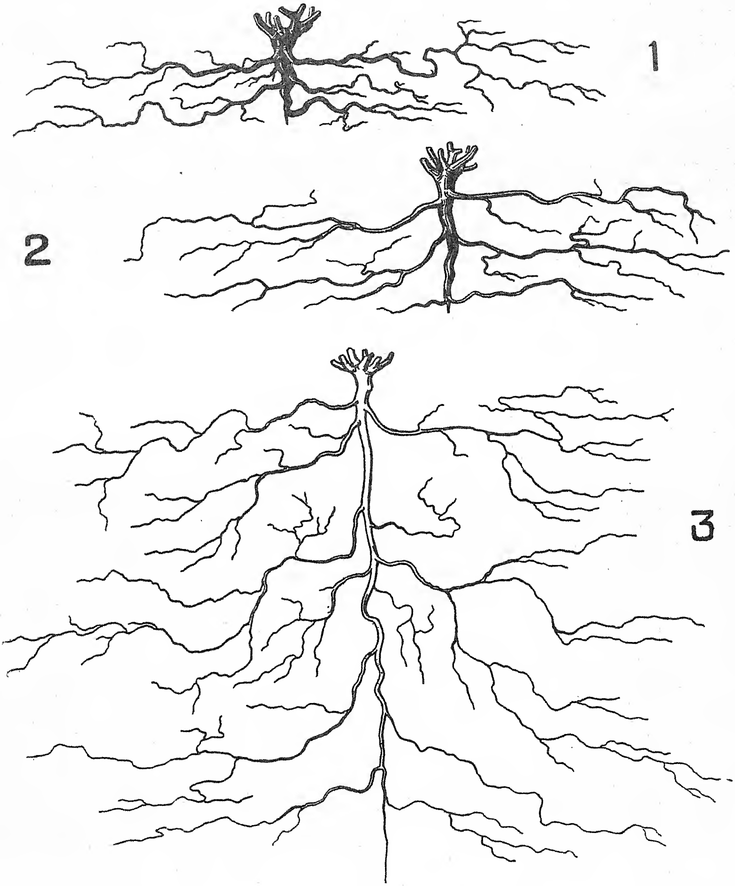
gram, leads to excessive vegetative growth before flowering time and to badly ripened seed. The effect of the type of soil on the yield of the same varieties is well seen in the results obtained on light and heavy land in 1912 and 1913 at Pusa. These are given in the following table :—

TABLE II.

Yield per acre of gram varieties at Pusa in 1912 and 1913.

Variety	1912 (light land)		1913 (heavy land)		
	Mds.	Srs.	Mds.	Srs.	
Local	14	27	4	0	West side of plot in 1913, land very heavy.
Type 14	23	35	3	24	
Type 17	30	31	3	22	
Type 9	32	16	15	8	
Type 16	13	28	10	0	
Type 18	34	27	9	28	East side of plot in 1913, land moderately heavy.

The behaviour, at flowering time, of the varieties grown on heavy wheat land in 1913 was quite unexpected. The whole plot, up to the end of January, gave promise of a record yield. After flowering, however, signs of weakness began to appear—the leaves commenced to fall and little setting took place, particularly towards the west side where the land was heaviest. All the symptoms pointed to root trouble of some kind and accordingly complete plants were dug up and the soil round the roots carefully removed by washing. It was found that the root-system was very superficial and somewhat diseased, particularly in the case of those plants which set no seed. No healthy nodules could be found on the roots of such plants. Where a few seeds only had set, the root development was somewhat deeper and more healthy with a few nodules but the characteristic of the whole set of varieties on the heavy land was superficial rooting and poor nodular development particularly where the soil contained most clay. Healthy plants, on higher, lighter land, were found to have normally developed root-systems and abundant, healthy nodules. The results obtained, as far as root development is concerned, are seen in Plate I opposite. Fig. 1 shows the root-system in the case of a plant which set no seed, while Fig. 2 shows that of a plant of the same kind which carried a few seeds. A normally developed root-system, drawn on the



SOIL-MOISTURE AND ROOT-DEVELOPMENT.

same scale, is shown in Fig. 3 which represents a plant from light, high-lying land about a hundred yards away.

Both as regards yield of grain, depth of rooting, and nodular development, the Pusa results of 1912 and 1913 are most significant. They show unmistakably the cardinal importance of thorough aeration of the soil for the development of an adequate root-system and for the production of healthy nodules. They also serve to explain the present distribution of gram in India and the damage to this crop which so frequently results when the air-supply of the roots and of the nodules is interrupted.

The distribution of gram in India has been referred to in Table I above (p. 214). If the Gangetic alluvium is considered, it will be seen that the area in Bengal is 176,000 acres while in the Province of Agra it is no less than 5,175,433 acres, there being a gradual increase in acreage through Bihar and Oudh. From the Meerut Division of Agra to Bengal, there is a regular soil transition from a somewhat sandy, open, well-drained loam with a relatively small proportion of natural soil moisture to an exceedingly fine silt of high moisture-retaining capacity. As the soil alters in texture towards Bengal, so the area under gram falls. In the Meerut Division, the soils are so open and aeration is so easy that the gram crop can be watered by canal irrigation with advantage but this is harmful at Pusa even on the lightest soils. Thus the distribution of this crop in the valley of the Ganges corresponds closely with the natural aeration of the soil. Wherever the roots of gram can obtain an abundant air-supply, the area is large. As the alluvium becomes finer and closer towards the Bay of Bengal, the area falls off and gram is only found on high, light land. Outside the Gangetic alluvium, the only areas where this crop is really important are the Punjab, Central India, and Bombay. In the Punjab, gram does best on sandy, open soils, and does not generally thrive under canal irrigation on such soils as those of the Chenab Colony. In Central India, the plant obtains abundant air for the roots through the natural cracking of the soil on which it is grown, while in Bombay the conditions are not dissimilar. In some parts of the Bombay Deccan, gram is ordinarily irrigated from wells and very high average yields of over 1,200 lb. per acre are common. Under such circumstances, it is interesting to note that the land which suits gram best is a black soil of medium quality and fair depth resting on *murrum*. This layer of *murrum* provides naturally excellent under-drainage. Thus the distribution of gram in India closely follows what may be called the natural ventilation of the soil and the better the aeration, the greater the density of the crop. Irrigation

is usual only in such cases as the Agra Province and the Bombay Deccan where the soils and subsoils are such that the porosity is not destroyed by flooding the surface.

Speaking generally, gram is a precarious crop. There are many references in the Indian literature to this point and to the damage which results if anything untoward happens at flowering time. Frost, lightning and moisture are generally the reasons given for the partial or entire wilting of gram which often takes place about flowering time. The chief cause of the trouble, however, appears to be interference with the air-supply of the nodules and roots, through crusts formed by rain, on soils which easily run together on the surface or become compacted. The roots and nodules easily turn black and die while the branches wilt from the growing point downwards. Heavy rain during growth has a similar effect on gram to that observed at Pusa when it is grown in heavy land well supplied with soil moisture.

The effect of interfering with the air-supply of this crop is well seen in the result of an experiment, carried out in 1915 at Pusa. A strip of gram was irrigated twice, on January 12 and February 25, and on one half of the watered area, nitrate of soda, at the rate of two cwt. per acre, was applied at each irrigation. Watering was found to check the growth, to turn the foliage a lighter green and to depress the yield by nearly 40 per cent. Irrigation, combined with nitrate of soda, had a much more marked effect. The colour of the foliage rapidly became yellow and many of the plants wilted away. The yield was only one-eighth that of the control plot—a reduction of nearly 88 per cent. This result is probably an aeration effect, due to the destruction of the tilth by the nitrate of soda, after which the air-supply to the roots would be greatly impeded.

The influence of the air-supply in the soil on the yield of gram received further confirmation at Pusa in 1915. This was a wet year and the season was not at all favourable for this crop. If the yield is limited by the aeration of the soil, it would be expected that under such conditions late, deep-rooting varieties would not do well and that the best results would be obtained from early-flowering, shallow-rooted types. It happened this year that three varieties, differing in time of flowering and in root development, were grown on a large scale on uniform land and a comparison was made between the yield and the average length of the main tap-root which developed laterals. The results are given in Table III and it will be seen that the yield in a wet year is inversely proportional to the extent of the root-system. For comparison, the yields of 1912, on similar land, in a very favourable year, are given in the last column.

TABLE III.

The relation between yield and root-development in a wet season.[1]

Variety	Date of flowering	Average length of tap-root bearing laterals	Area, in acres	Yield per acre, 1915		Yield per acre, 1912	
				m.	s.	m.	s.
Type 9	Feb. 18th	16 cm.	1·5	12	22	32	16
Type 17	Feb. 4th	13 cm.	1·0	18	9	30	31
Type 18	Jan. 18th	8 cm.	1·0	23	27	34	27

The cultivators themselves, as far as their practice is concerned, recognize that an open soil is best for gram and that air in the soil is more important than moisture. In many parts of the Punjab, sandy soil is considered most suitable for the crop and the surface, after sowing behind the plough, is often left rough. There is no effort to conserve the surface moisture by means of the beam as is so often the case with crops like wheat.

As in other leguminous crops, the presence in the soil, in sufficient numbers, of the nodule organisms is necessary for the rapid growth of gram. Grown on new land for the first time at Pusa, it is observed that the crop is often thin and poor and that the nodules are almost entirely absent. Moistening the soil with water, containing crushed nodules, leads to the formation of these bodies and it is observed that when the crop is repeated the second year on new areas it improves considerably. In extending the cultivation of this plant to new localities, it would probably pay to import a little gram soil with the seed so as to inoculate the land with the nodule bacteria and to grow the crop at least two years before coming to any decision as to its local value.

II. POLLINATION AND NATURAL CROSS-FERTILIZATION.

FLOWERING.

The flowers are borne singly on the branches on short, jointed peduncles, from half to three-quarters of an inch long, which arise opposite the leaves. The lowest buds open first and the cymose arrangement of the flowers is shown in Plate II.

[1] A result, such as the above, brings out the importance of detail in variety trials in India. But for the determination of the depth of the root-system, the reason for the reversal of the 1912 results in 1915 would not have been evident.

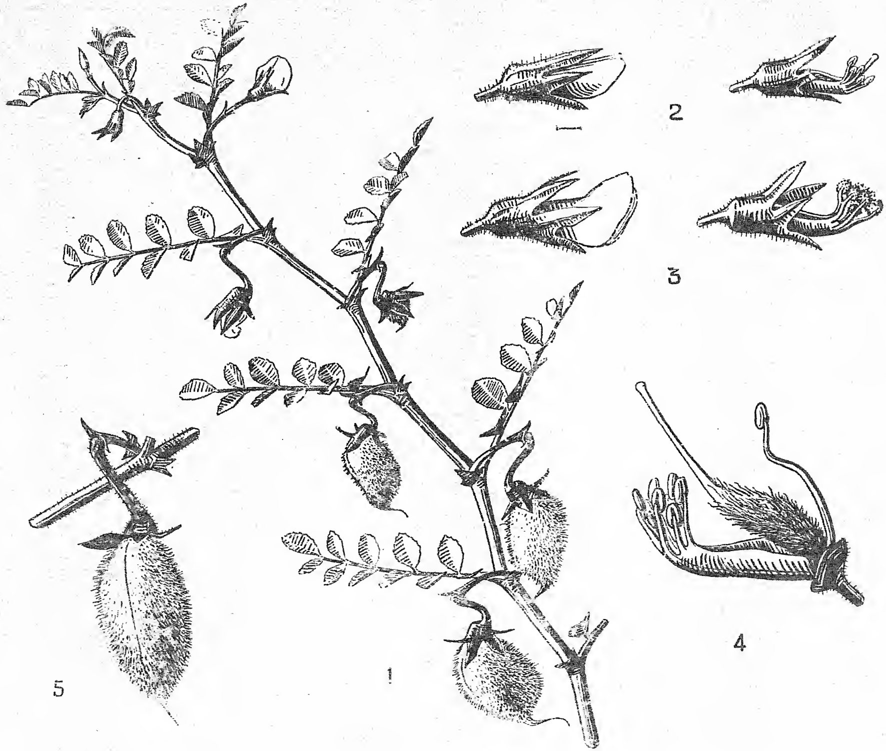
The buds open during the day from about 9 A.M. to 4 P.M. and close again the same afternoon a little before sunset. As a rule, they open again the next morning from 8·30 to 10 A.M. and close again finally in the late afternoon. In 1914, observations were made, towards the end of February, on the flowering of five different varieties and, in all cases, the results were similar, the flowers opening on two consecutive days as indicated above. In 1915, more detailed observations were made of the opening and closing of sixteen flowers of one variety the results of which are given in Table IV.

TABLE IV.

Duration of opening of gram flowers.

No. of bud	February 8, 1915		February 9, 1915		Duration of opening	
	Time of opening	Time of closing	Time of second opening	Time of final closing	h.	m.
1	11/44	17/45	8/30	17/20	14	51
2	11/35	17/45	8/30	17/20	15	0
3	11/30	17/20	10/00	18/30	14	20
4	11/45	17/20	10/00	17/20	12	55
5	14/10	17/30	10/00	17/45	11	5
6	14/00	17/30	10/00	17/20	10	50
7	13/30	17/45	10/00	17/45	12	0
8	15/20	16/45			1	25
9	14/20	16/45	Opened partially at 10/30	closed at 16/0	2	25
10	14/00	16/45			2	45
11	15/20	16/45			1	25
12	12/00	16/30	Did not re-open		4	30
13	15/00	17/45	9/20	16/05	9	30
14	15/00	17/45	9/20	17/30	10	55
15					Did not open	
16						

The time during which each flower remains open is therefore somewhat variable and ranges, in the case of those which open normally on two consecutive days, from seven and a half to fifteen hours. As a rule, there is only one flower open at a time on each branch but when the growth is very vigorous, two may be open simultaneously. The position of the buds and flowers changes



FLOWERING DETAILS IN GRAM.

a good deal during the flowering period. In the bud stage, the flowers droop but grow out into the light and air as they open. During the second day, the peduncle begins to be deflexed at the joint and, by the time the flower has faded on the fourth day, the bending is complete. The various stages in the extension and deflexion of the flower stalk are shown in Plate II.

The colour of the corolla soon fades. The pink flowers first turn blue, then colourless and finally brown. The blue flowers retain their colour till they fade. The small pods emerge from the faded corollas about five or six days after the flower finally closes. They attain their full size three or four days later but, at this stage, the seeds are very small and the pods appear empty. From ten to twelve days more are necessary for the seeds to attain their full size in the pod. Flowering goes on in each plant for more than a month but the rapid rise in temperature in March, often accompanied by drying winds, ripens off the whole crop with such rapidity that the last formed seeds have no time to mature in a normal manner.

Pollination.

In the bud stage, the anthers occur grouped round the style at a short distance below the stigma (Fig. 2, Plate II). Dehiscence takes place in the bud a day before the flower opens and, when the pollen is first liberated, the stigma is still above and quite free from the burst anthers. The filaments now gradually increase in length sufficient to carry the burst anthers above the stigma (Fig. 3, Plate II). This stage is completed before the flower opens and thus the act of pollination takes place in the bud. It would be expected therefore that self-pollination is the rule. That this is so is confirmed by the behaviour of ten plants which were placed under nets in 1914. All set normal seed without any difficulty, thereby proving that insect visitors are not necessary to bring about pollination.

Bees visit the flowers in great numbers so that there is some possibility of crossing. On cloudy days, the pollen grains stick together and give out a yellowish, watery substance. In such cases, little or no setting takes place and, even if pods are occasionally formed, no seeds are developed. Such empty pods occur in large numbers in the case of Type 13 and in those plants in the progeny of natural crosses which have rounded seed similar to those of this type. Unproductiveness seems associated with this rounded grain-shape.

Some observations were made in 1915 on the effect of wet, cloudy weather and of moist air on pollination. January 27 and January 28 were both cloudy days and flowers were marked on the morning of the second day just as

they were about to open. The number of pods formed was afterwards determined. The results are given in Table V.

TABLE V.

Effect of cloudy weather on setting.

No. of culture	Total number of marked flowers	Number of pods which formed	Percentage of setting
Type 15	27	11	41
Type 8	9	1	11
Type 7	6	0	0
Type 19	13	0	0
TOTAL	55	12	

The first of these cultures, Type 15, was in full flower at the time of the experiment, the rest were only just beginning to flower.

A more detailed set of observations was made on February 5. February 3, 4 and 5 were wet and cloudy days, during which an inch of rain in all fell. On February 5th, small labels were placed on many branches at a point just underneath the last opened flowers. The flowers just below the labels must have opened during the wet and cloudy weather, while those above opened after the rain. The results are given in Table VI.

TABLE VI.

Effect of rainy weather on setting.

Variety	FLOWERS BELOW THE LABELS			FLOWERS ABOVE THE LABELS		
	No. of flowers	Pods formed	Percentage set	No. of flowers	Pods formed	Percentage set
Type 23	18	2	11	18	15	83
Large Kabuli	18	4	22	18	13	72
Type 22	21	5	23	21	17	81
Type 21	19	1	5	19	12	63
Type 20	20	9	45	20	18	90
TOTAL	96	21		96	75	

The effect of the rainy and cloudy weather was therefore most marked and the setting was only about a fourth of what took place immediately the

weather cleared. The best setting occurred in the case of the last culture which, at the time of the experiment, was in full flower. Unfavourable conditions seem to affect the setting of plants, just beginning to flower or just going off their bloom, much more than those in full flower.

The effect on setting, during bright weather, of moist air round the flower is very similar to that which occurs during rain and cloud. Flowering branches were placed in tubes, closed to varying extents and also in ordinary, elliptical lamp-chimneys, open above and closed lightly with cotton wool below. When the tubes were completely closed and no air circulation was possible, the buds did not open and no setting took place. Where the tubes and lamp chimneys were opened, to varying extents, to the atmosphere and where some air circulation was possible, a little setting took place. In the case of forty buds which opened in large lamp chimneys, open above and lightly closed below with cotton wool, only 8 (20 per cent.) of the flowers set seed.

The experiments indicate the enormous effect of high humidity on setting and show the loss which must follow from even light rain or damp cloudy weather at flowering time. Thus rain at this period may damage the gram crop in two ways—by preventing setting, and if the fall is large, by interfering with the aeration of the roots and nodules causing the whole plant to wilt.

No cases of parthenogenesis occurred at Pusa when the stigma or stamens were removed prior to flowering.

Natural Cross-fertilization.

While self-pollination is the general rule in gram, nevertheless natural crossing occurs occasionally in this crop. The first cases were suspected in 1911 at Pusa when, in a large plot of a pure culture of Type 13, a blue flowered variety, some seeds were observed different in shape and colour from the general plot. These resembled, to some extent, those of Type 9, a white flowered variety, which was growing side by side. These stray seeds were grown singly and in 1912 produced plants with different flower colours—white, blue and various shades of pink. Some single plants, raised from these seeds, were selected in 1912 and their subsequent progeny, as regards flower colour, is given in the following :—

(1) Six plants, with white flowers, bred true in 1913.

(2) One blue flowered plant bred true and three other plants with blue flowers split into blue and white—18 blue : 12 white ; 23 blue : 8 white ; 13 blue : 7 white. This gave a total of 54 blues to 27 whites or a ratio of 2 : 1.

(3) Of eleven plants with various shades of pink flowers, only four bred true as regards flower colour. The rest split as follows :—

No.	Progeny in 1912-13		
	White	Blue	Pink
4	6	4	9
6	7	3	12
8	5	3	10
9	4	3	10
10	9	2	12
12	6	4	10
11	0	4	12

A second case of natural crossing was observed in 1911 in a plot of Type 1, a white flowered variety. Two plants, with pink flowers, were observed in 1912 which split during the next year into—3 white: 11 pink; 6 white: 12 pink—thus giving a total of 9 whites: 23 pinks.

The single plants of 1913, connected with the above cases of natural crossing, were grown on the following season and the results confirm those of 1913.

Pink flowered plants (17).

(1) Four, which produced 98 plants in all, bred true as regards pink flowers.

(2) Four split into pinks and whites only—7 pink: 2 white; 12 pink: 5 white; 11 pink: 2 white; 51 pink: 18 white—total 81 pinks: 27 whites or a ratio of 3 : 1.

(3) Three split into pinks and blues only—15 pink: 6 blue; 23 pink: 11 blue; 27 pink: 10 blue—total 65 pinks: 27 blues or a ratio of 2·4 : 1.

(4) Six split into pinks, blues and whites as follows :—

No. of culture	Progeny in 1914		
	Pink	Blue	White
4 (9)	24	3	8
8 (1)	3	6	2
8 (2)	45	13	8
9 (1)	6	1	2
9 (2)	52	22	27
10 (4)	5	2	2
	135	47	49

White flowered plants (30).

Twenty-eight of these bred true as regards flower colour and splitting took place in two cases only. One culture produced 22 whites and 2 pinks and another gave 8 blues and 9 whites. The former of these was probably a case of fresh crossing, while in the latter there must have been a mistake in observation in 1913.

Blue flowered plants (8).

(1) Three bred true and produced 35 blue plants in all.

(2) Four plants split into blues and whites only—8 blue : 4 white ; 9 blue : 5 white ; 12 blue : 6 white ; 7 blue : 1 white—total 36 blues : 16 whites.

(3) One plant split into 6 blues and 3 pinks.

In addition to the splitting as regards flower colour, there appeared to be segregation, as regards grain shape, into ordinary and rounded grains.

The above observations on the behaviour of the progeny of the natural crosses were not made in sufficient detail for the deduction of the various colour factors present in the flowers. A subsequent critical examination of the types showed that there are several grades of pink flowers.

III. CLASSIFICATION AND DESCRIPTION OF THE TYPES.

The raw material used in the study of this crop consisted of collections of country seed obtained from Aligarh, Muzaffarnagar and Saharanpur in the United Provinces and of collections of local Bihar gram. Form separation was commenced in 1909 and was continued in succeeding years. In all cases, the cultures were started, either from a single seed or from the seed of a single plant.

That the Indian gram crop is not uniform but consists of several distinct forms, distinguished by the colour of the seed and of the flowers, has long been vaguely recognized and there are frequent references to these kinds in the literature. The most definite recognition of the existence of these types in the older literature is to be found in the following description of gram in Duthie's *Flora of the Upper Gangetic Plain* (p. 256) :—

" A viscid, much-branched annual. *Leaves* 1-2 in. long, with usually a terminal leaflet ; *stipules* small obliquely ovate, toothed ; *leaflets* about 1/4 in.

long, ovate, oblong or obovate, deeply cut. *Peduncle* 1/4 to 3/4 in., jointed about the middle, deflexed after flowering. *Calyx* 1/4 to 1/3 in., teeth linear. *Corolla* scarcely half as long again as the calyx, pink, blue or white. *Pod* 3/4 to 1 in., turgid, pubescent, topped by the persistent base of the style. *Seeds* obovate or subglobose, beaked, reddish brown, black or white.

Largely cultivated in North-West and Central India during the cold season. Although not now to be found in a truly wild state, its original home was most probably in some part of South-East Europe. Two distinct kinds are grown in this part of India, one with reddish seeds, and a smaller kind with seeds of a light brown colour. There is also one with nearly black seeds and another with large white seeds, known as "Cabuli," the last named is, however, rarely grown for profit."

The characters in which the various varieties and types of gram differ from each other must first be considered before their classification is dealt with.

Morphological Characters.

Beyond the great range in the colour of the flowers and seeds, which occurs in this crop, the differences between the various types are not, at first sight, easy of exact expression. By growing the kinds in oblong blocks, so arranged that they can be compared in the early morning light, the somewhat elusive vegetative differences become much more obvious. The massed habit then becomes useful in distinguishing forms which otherwise would defy classification.

Habit. The group of types—1 to 5—which make up what is known as the "large Kabuli gram" stand out quite clearly from the crop as cultivated under field conditions in India. These have light foliage, white or whitish green flowers and they are considerably taller with larger leaflets than the country crop. Their seeds are much larger than those of ordinary gram and are always whitish in colour.

With the exception of Type 9, the rest of the twenty-five kinds are somewhat similar in general habit apart from the colour of the foliage and time of maturity. The main branches give off, as a rule, not more than one secondary shoot and the general habit is erect. Type 9, however, is quite different in this respect. The crown divides up into several main arms at the surface of the ground and the main branches give off numerous laterals. The extreme range in habit in this crop is shown in Fig. 1. The left-hand sketch shows the

mode of branching most usually observed while, on the right, the habit of Type 9 is represented.

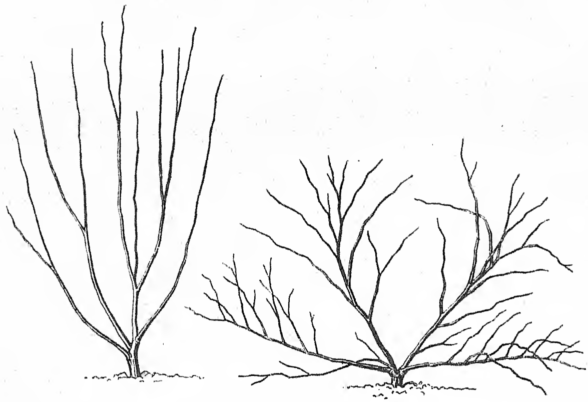


Fig. 1. The range in general habit in gram.

Closely correlated with the habit and time of flowering is the general extent of the root system and the depth to which laterals are developed on the main tap-root. As a rule, the late sorts are more deep rooting than the early types as will be seen on reference to Table III above (p. 219). It has not been usual hitherto, in considering the habits of varieties, to pay much attention to the root-system. A little consideration, however, will make it clear that this will have to be taken up in the future, particularly in the case of Indian economic plants.[1]

Leaves. The types differ considerably both in the total length of the leaf, in the size and number of the leaflets as well as in the tone of colour of the foliage. Types 1 to 5 have comparatively large leaflets and stand out in this respect from the remaining forms. The small colour differences between

[1] The extent of development of the root-system will often assist the investigator in judging of the suitability of a variety for a given tract of country and for a particular set of soil conditions. It is quite possible that the plant-breeders of the future will study the inheritance of characters relating to the root just as minutely as they have done in certain of the above-ground characters dealing with flowers and seeds. In India, where the supply of water and air to the roots is so important, much of the future work on crops is likely to be devoted to the subterranean portions of the plant.

Types 6 to 25 are best studied when the kinds are massed in oblong plots. In a few cases, the margin of the leaflets is red. The large glandular hairs on the margin of the leaflets often contain coloured cell-sap, which may either be yellow, red or blue.

Flowers. The colour of the corolla may be greenish, white or various shades of pink or blue. In fading, the pink flowers turn blue before withering.

Seeds. The colour of the seeds varies from whitish to blackish through various shades of yellow and red. There is a considerable difference in colour in the seeds of any one plant, but this is due to the fact that the last formed grains have no time to ripen on account of the rapid onset of the hot, dry weather.

Classification of the Types.

The twenty-five types of gram, so far isolated at Pusa, can be distinguished according to the following classification provided full use is made of the massed habit and of all the vegetative differences.

I. Plants, leaves, flowers and seeds large.

1. Flowers greenish, standard and wings hairy, standard persistent.

Type 1. Very late, erect, leaves dark green, seeds white with a reddish yellow tinge.

2. Flowers white, corolla glabrous, standard caducous.

A Plants early.

Type 2. Very early, leaflets large.

Type 3. Early but later than Type 2, leaflets rather small.

B. Plants late.

Type 4. Similar to Types 2 and 3 except in time of maturity.

C. Plants very late.

Type 5. Leaves very dark green.

II. Plants, leaves, flowers and seeds small.

1. Flowers white.

A. Seeds white with a yellowish tinge.

(*a*). Plants early.

Type 6. Leaves light yellowish green.

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MEMOIRS OF THE DEPARTMENT OF AGRICULTURE IN INDIA

STUDIES IN INDIAN OIL SEEDS

No. 1. SAFFLOWER AND MUSTARD

BY

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INDIAN SAFFLOWER.

I. INTRODUCTION.

Safflower (*Carthamus tinctorius*, L.) is widely cultivated in India, both as an oil-seed and for the reddish dye in the flowers (carthamin). Watt, in the *Commercial Products of India*, states that there are two main "conditions," one grown for its flowers, the safflower dye of commerce, the other for its oil-yielding seeds, the *kusum* oil of trade. The former is said to be fairly extensively cultivated in Bengal, the United Provinces, the Central Provinces and Bombay. The best dye is said to come from the Dacca Division of Bengal and the best *kusum* oil from the Deccan. Open sandy soils suit the crop, which is generally grown mixed with gram, barley or wheat. On this account, the area under safflower is not recorded separately in the statistics of Indian crops. The export of safflower dye is small and, in 1912-13, amounted only to 4,250 cwt. which for the most part was sent from Calcutta to the Straits Settlements and Hongkong. In addition to the oil, the dye in the flowers is largely used by the people in India and, in spite of the competition of aniline dyes, still maintains its position. The rose-coloured turbans worn by the Marwari traders of Rajputana are dyed with safflower. Duthie and Fuller, in *Field and Garden Crops of the North-West Provinces and*

Oudh, state that the great demand for the dye from Rajputana accounts for the large area under safflower in the Meerut Division, the dye finding its way to the consumers through the market at Delhi.

The dye occurs in the florets which, after the setting of the seeds, are collected as frequently as possible. Two colouring matters occur—a yellow pigment soluble in water and safflower red (carthamin) insoluble in water but soluble in alkalis. After the collection of the florets, the crop is allowed to ripen its seeds from which *kusum* oil is extracted. This is used locally, both for culinary purposes and also as an adulterant of *ghi* and of *til* oil.

Since 1908, the safflower crop has received some attention at Pusa and twenty-four different types, breeding true, have been selected from seed obtained from Bihar, Bombay, Sind and the United Provinces. These types cover a wide range of forms both as regards habit, foliage and the distribution of the red colouring matter in the flowers.

II. BIOLOGY OF THE FLOWER.

Flowering.

The capitula are borne at the ends of the branches well beyond the large leaves. Each main branch ends in a capitulum, the flowers of which begin to open before those of the inflorescences on the secondary branches. As soon as these secondary branches have completed their growth in length and have carried their single capitula to the flowering region, flowers begin to appear in these inflorescences. Flowering begins in the inflorescence which terminates the main axis of the plant, followed by the first formed capitula of the main branches. The secondary and tertiary branches continue the process in regular order. The total flowering period varies from three to four weeks and usually takes about twenty-five days.

Pollination.

The florets at the margin of the capitulum open first and flowering proceeds centripetally, the whole taking about four days. They usually begin to open in the morning and the process goes on till mid-day. A few, however, open in the afternoon. They remain open one or two days before fading. In the bud stage, the style elongates and the stigma usually emerges from the anther tube before the pollen is liberated. Soon after the extrusion of the stigma, the corolla opens and anthesis takes place while the hairy portion of the style is still within the tube. The continued growth in length of the style enables the numerous hairs to sweep a large amount of

the pollen from the tube into the open air. An examination of the florets at this period shows the stigma in the great majority of cases quite free from pollen, but with numerous grains adhering all round the hairy region of the style. In some cases, however, anthesis takes place before the extrusion of the stigma thus rendering self-pollination possible. Bees visit the capitula in large numbers in the mornings and pay particular attention to the newly opened florets in which anthesis has already taken place. They clear away the pollen adhering to the style and to accomplish this have to stroke it in the direction of the stigmatic surface. In this way, a few pollen grains are carried to the stigma and pollination takes place. By this method of transference of pollen from the anther to the stigma, both self- and cross-pollination are bound to take place as the bees work daily on all the types of plants with open flowers. Besides this method of pollination, it will be evident that the slightest movement of the capitulum by wind or by the operations of the bees might easily carry pollen from one flower to its neighbour and geitonogamy is thus easily possible. Both self- and cross-pollination are therefore likely to take place in this crop. A consideration of all the facts points to the probability that selfing is much commoner than crossing.

Very little setting takes place under parchment paper bags as compared with the results observed in the case of free-flowering inflorescences. On the other hand, when the plants are enclosed, either in muslin or mosquito nets, this difference largely disappears as will be seen from the observations summarized in Table I.

TABLE I.

Setting of protected and free-flowering plants.

No. of culture	Date when first flower appeared	Average number of seeds per head				
		1911		1914		
		Bagged	Free-flowering	Bagged	Netted	Free-flowering
1	2-3-14	9	41	9	25	22
4	25-2-14	19	51	19	35	43
5	16-2-14	9	27	1	27	25
6	14-2-14	3	34	12	24	33
56	23-2-14	5	50	18	48	48
38	23-2-14	7	39	21	36	28
39	20-2-14	1	30	1	36	38

TABLE I.—*contd.*

Setting of protected and free-flowering plants.

No. of culture	Date when first flower appeared	Average number of seeds per head				
		1911		1914		
		Bagged	Free-flowering	Bagged	Netted	Free-flowering
2	23-2-14	15	33	8	27	30
3	23-2-14	10	46	15	44	40
12	23-2-14	6	57	7	37	35
13	20-2-14	6	24	26	29	26
14	2-3-14	16	42	3	26	22
15	25-2-14	7	41	14	54	43
30	20-2-14	14	65	16	28	39
27	27-2-14	9	54	13	50	49
31	23-2-14	9	35	5	23	23
32	23-2-14	26	58	5	28	40
34	20-2-14	15	48	15	38	41
42	25-2-14	15	68	14	42	45
17	3-3-14	9	54	18	38	50
8	9-3-14	21	48	3	31	39
10	14-3-14	7	54	5	36	38
23	2-3-14	10	46	10	44	41
24	10-3-14	6	54	13	40	52
20	4-3-14	18	55	15	51	44
	AVERAGE	11	46	12	32	37

These results show that the visits of insects like bees are not necessary for pollination provided that air movement and the natural humidity are not interfered with. Under parchment paper bags, there is necessarily little air movement and the chances are small of the stigma of one flower coming in contact with the pollen covered style of its neighbour at the proper moment. Further, the higher humidity and possibly the higher temperature inside the bag would both tend to reduce the amount of pollination. Under large nets, which cover almost the whole flowering portion of the plant, there is little difference between protected and unprotected flowers as regards air movement, humidity and temperature and under such circumstances geitonogamy is readily possible and is observed to take place.

In order to determine the effect of increased humidity on pollination, a comparison was made in 1915 between setting in lamp chimneys, closed below and partially open above, and in the free air. The results are set out in Table II.

TABLE II.

The effect of increased humidity on setting.

Culture	Number of seeds in each Capitulum	
	In lamp chimneys	In free air
1	0	21
	0	11
	1	31
	0	27
25	0	48
	1	40
	0	52
	6	50
2	3	21
	0	43
	0	34
8	0	52
	0	37
	0	23
	1	39
15	13	63
	13	55
TOTAL	38	647
AVERAGE	2·2	38

The inhibiting effect of the moist confined air is very great and, at first sight, the result would be put down entirely to the effect of the increased humidity. It is possible, however, that temperature plays a part and that pollen grains will not germinate readily in moist, hot air.

It is found that while the number of seeds set in free-flowering capitula on the same plant at any particular period is to a great extent uniform, nevertheless there is very great variation in the number set under parchment bags. No setting at all takes place in many cases under bag as will be seen from the results set out in Table III. In some cases, such as cultures 5 and 8, the influence of the bag is far less deleterious than in others. The cause of this great variation has not been investigated.

TABLE III.

Setting in individual heads on the same plant.

No.	Kind of head	Number of head											Total no. of seeds		
		1	2	3	4	5	6	7	8	9	10	11	Bagged	Free-flowering	Average
1	Bagged	1	17	14	0	0	0	0	0	0	0		3		0·3
	Free-flowering	34	34	37										105	35
2	Bagged	2	8	10	1	6	16	12	9	0	0	0	63		5
	Free-flowering	46	42	34	40	26								188	38
3	Bagged	15	9	15	12	5	19	1	18	2.	1	15	131		11
	Free-flowering	34	35	30	29	40	33							201	34
4	Bagged	12	5	3	12	12	10	0	0	0	0		54		5
	Free-flowering	34	48	39	34	47								202	40
5	Bagged	22	23	12	27	28	8	23	26	0			169		19
	Free-flowering	37	35	37	35	35								179	35
6	Bagged	13	22	23	10	4	22	3	2	0	0	0	99		9
	Free-flowering	61	64	70	57	65								317	63
7	Bagged	8	22	4	6	11	2	0	0	0	0		53		5
	Free-flowering	54	45	53	54	52								258	52
8	Bagged	24	8	5	27	28	25	22	0	0	0		139		14
	Free-flowering	61	41	51	44	47								244	49

Average number of seeds per head { Bagged 9. Free-flowering 43.

The effect of the season on the amount of setting in *rabi* crops at Pusa is particularly well-marked. As a rule, all late varieties set badly and the last formed flowers, even on early kinds, do not produce many seeds. This point was investigated in 1915 in the case of four safflower cultures. The results are given in Table IV from which it is clear that, with one exception, there is a rapid falling off in seed production. So great is this at Pusa that the utmost care has to be taken, in making comparisons, that the observations are made on cultures in similar phases of flowering.

TABLE IV.

The effect of the season on setting.

Type	Average Number of Seeds per Capitulum		
	Early	Intermediate	Late
20	51·7	41·7	29 9
17	19·9	23·3	25·7
13	44·3	39·9	11 9
Dacca	31·0	—	24 7
AVERAGE	36·7	34·9	23·2

A consideration of the development of the flower and of the results of the pollination experiments described above leads to two very definite conclusions. Self-pollination is likely to be the rule in safflower but a fair percentage of natural crossing is also possible. The effect of flowering in confined space, such as in paper bags or in partially closed glass vessels, is to reduce pollination and to interfere very considerably with the number of seeds set. How far temperature is a factor in pollination, under such circumstances, has not been determined but it is probable that it has some influence.

NATURAL CROSS-FERTILIZATION.

The extent to which natural crossing has produced heterozygotes in safflower in Bihar has been referred to in a previous paper.[1] Out of 76 single plants selected, only two bred true in all respects. Variation occurred in many directions, namely, in the colour of the flowers, in the habit of the plants, whether tall or spreading, in the degree of hairiness and of spinosity of the bracts of the inflorescence and also as regards the characters of the leaves.

The colour of the florets in the bud stage varies from whitish through various shades of yellow to reddish. These colours are best seen just as the

[1] *Mem. of the Dept. of Agr. in India (Botanical Series)*, vol. III, no. 6, 1910.

buds are ready to open. When fully opened, the amount of red colour in the corolla appears to diminish but on fading the redness develops (Plate II). All the whitish and some of the pale yellow flowers bred true but many of the plants with orange florets were heterozygotes and when grown singly gave all stages from yellow to deep orange.

Subsequently, the proportion of heterozygotes was determined in the crop as grown in other parts of India. Out of 22 samples from different places in the Bombay Presidency, 20 proved to be almost pure and these were characterized by a copious development of spines on the leaves and bracts. Three distinct types only were found in these collections from which it appears that the kinds are kept much purer by the people in Bombay than in Bihar. In contrast with these almost pure cultures, the seed received from Ahmedabad and Larkhana (Sind) was very mixed and an examination of the progeny of single plants showed the existence of extensive natural crossing. No less than nine types were finally selected from these two samples. Two samples of seed from Mirpurkhas in Sind were considerably mixed and from these five types were isolated. Two samples from the United Provinces proved to be almost pure and yielded only two types which were characterized by spinose bracts. It will be seen therefore that the safflower crop in India varies greatly in gametic constitution. In some cases, as in the Bombay Presidency, practically pure types are grown whereas, in Bihar and Sind, it is largely made up of heterozygotes.

In order to determine to what extent cross-fertilization takes place at Pusa, when the various types are grown next to next in pure culture, the seed from unprotected flowers of the 1914 crop was sown in the case of four types and the progeny examined. The results are given in Table V from which it will be seen that about sixteen per cent. of the flowers were cross- and the remaining eighty-four per cent. self-fertilized.

TABLE V.

Percentage of crossing at Pusa in 1914.

Type	Total number of plants	Heterozygotes	Percentage of crosses
10	78	9	11·5
11	93	14	15
12	70	19	27
13	80	10	12·5
TOTAL	321	52	AVERAGE 16·5

Since 1910, many of the types of Indian safflower have been raised continuously at Pusa from the seed of protected flowers and all crossing has been prevented. No evidence of loss of vigour from this continuous self-fertilization has been observed. The growth has been robust, the plants have done well and no difficulties have been met with in germinating the seeds. So far, natural crossing does not appear to be essential in maintaining the vigour of the crop.

III. CLASSIFICATION AND DESCRIPTION OF THE TYPES.

Safflower is described in *Field and Garden Crops of the North-West Provinces and Oudh* (I, 51) as follows :—

" A glabrous thistle-like herb with reddish orange flowers. Stems about 2 ft. high, much branched above. Leaves sessile, oblong lanceolate, with serrate aculeate edges or nearly entire. Flowers in large compact heads; outer involucre bracts leafy, ovate oblong, constricted above the base, entire or spinulose, inner bracts narrower. Florets tubular, hermaphrodite or a few of the marginal ones sterile, tube slender, limb oblong. Anthers sagittate at the base. Achenes $\frac{1}{4}$ in., smooth, obovoid, truncate at the top, obliquely 4-angular, with four projecting ribs."

There are several references in the Indian literature to the occurrence of different forms of safflower. The great contrast between the varieties with spinose and entire bracts is noted by Watt in the *Commercial Products of India* as well as the existence of varieties with yellow as opposed to reddish florets. He states " speaking broadly, the oil-yielding forms are more spinose than the dye-yielding and have usually yellow coloured flowers, the dye forms being orange and even yellow tinted with scarlet." Duthie and Fuller refer to the effect of high cultivation in reducing the spiny character of this crop.

The earlier observers regarded the crop from the point of view of systematic botany and no separation of the types from the mass of heterozygotes was carried out. This has now been done at Pusa in sufficient detail to give an idea of the range in form which exists in Indian safflower.

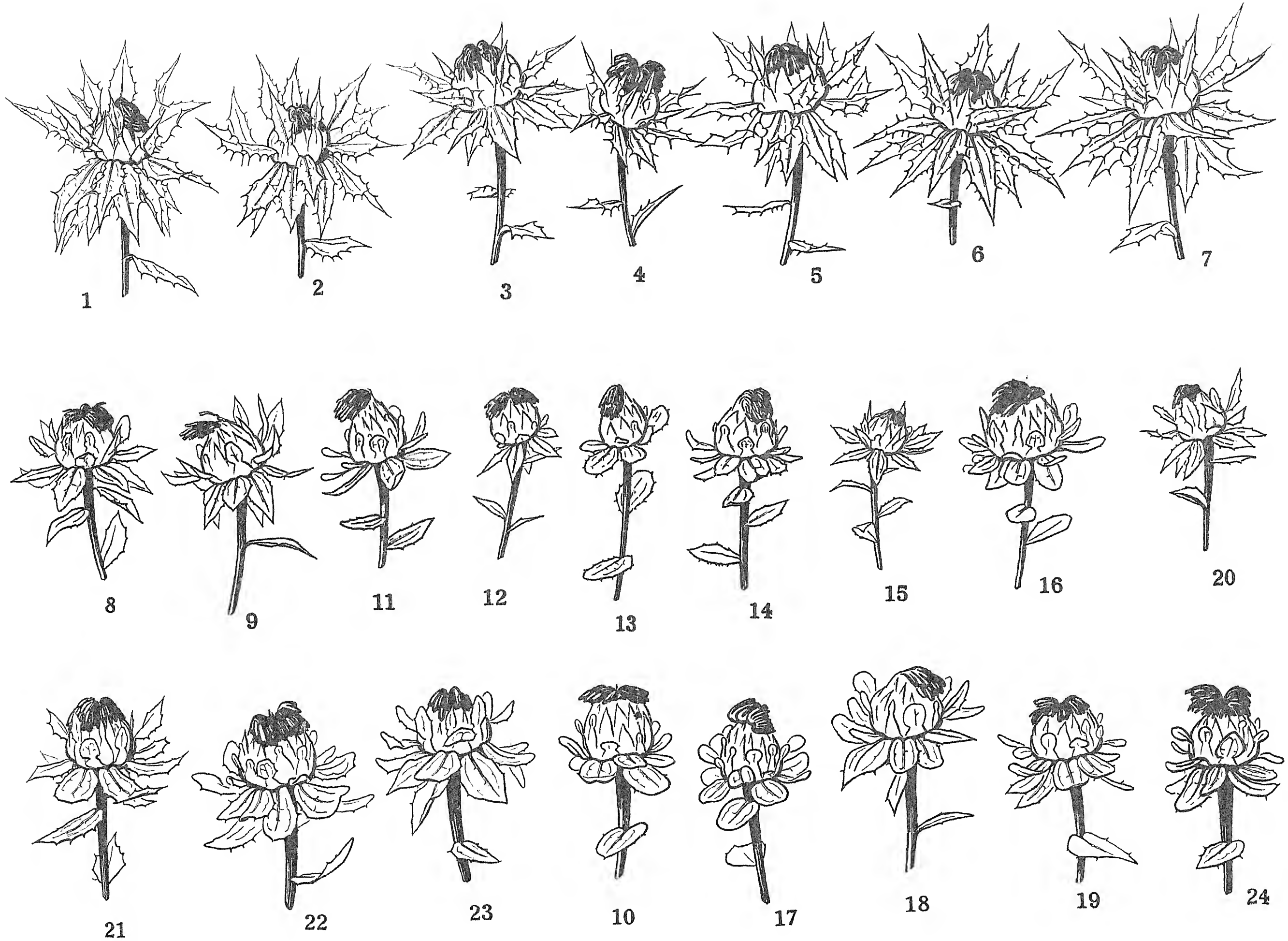
Morphological Characters.

The types of Indian safflower vary greatly particularly as regards the general habit, the leaves, bracts and florets. These facts render the classification of the types and their description a comparatively easy matter.

Habit. The great differences met with in general habit depend on the height, on the angle at which the secondary branches are given off and also on the point on the main stem where branching begins. The range in height of the various types is considerable, the limits in 1914 being 100 and 170 cm. The general angle at which the secondary branches arise from the main stem also shows a wide range from rather dwarf, spreading, well-branched plants to tall forms in which the branches are close to the stem. Approximate measurements of these angles showed that the limits were 15° to 45°. The habit is also influenced by the point on the main stem at which branching begins. The open, spreading forms begin to branch low on the stem, about 5 cm. from the ground, while the tall forms of closer habit do not give off their first laterals below 30 cm. from the base.

Leaves. The large, lower leaves, which are always practically free from spines, vary greatly as regards the margin and the extent of division. The margin usually ranges from wavy to deeply dentate, while in some types the leaves are entire, in others they are divided almost to the midrib. In the late types, the internodes near the base are very short and in these there appears to be a tuft of radical leaves; in the earlier forms, the internodes are more evenly distributed. In all the types, the leaves diminish in size from below upwards and, in all cases, the upper leaves are more or less spinose. In some types, however, the spines are very small while in others they are highly developed and are both long and numerous. In the massed habit, the differences in leaf-colour between the types become evident. The tone varies from light to a very dark green.

Bracts. In the involucral bracts there is also a great range in form (Plate I). In all the types, the outer bracts are constricted above the base and are always foliaceous and often spinescent. The basal, imbricated portions of the bracts are without spines but these are more or less developed on the foliar part above the constriction. There are great differences among the types in the size, shape, indentation and degree of development of the spines of the foliar portions of the involucral bracts. Those types with spinose upper leaves develop this character in the bracts, while in the almost spineless forms the spines on the bracts are few and short. In some types, the lower imbricated portions of the bracts are covered with soft white hairs, in others, these are nearly absent and the unopened buds look green. The hoary or green appearance of the capitulum is a remarkably constant character and one that has been made use of in classifying the types.



INVOLUCRAL BRACTS IN THE TYPES OF INDIAN SAFFLOWER.

Florets. The colour of the florets varies from whitish to almost red (Plate II). Between these extremes, yellowish and slightly reddish intermediate types occur. These differences arise from the yellow and red colouring matters in the floret and the degree to which the red colour is developed can be seen both in the unopened buds and in the faded corollas.

Classification of the types.

I. Outer bracts lanceolate, distinctly spinose.

1. Bracts smooth, green.

A. Florets white.

Type 1. Plants tall, erect, leaves dark green, incised. Intermediate as regards time of flowering, very late in ripening.

B. Florets yellow, not turning red on fading.

Type 2. Plants intermediate in height, spreading; leaves light green, incised, bracts long. Intermediate as regards time of flowering.

Type 3. Plants intermediate in height, spreading; leaves dark green, serrate. Very early.

Type 4. Plants short, spreading; leaves very light green, margin dentate; bracts short and narrow. Very early.

C. Florets yellow, turning to red on fading.

a. Flower buds yellow with a red dot on the apex.

Type 5. Plants intermediate in height, somewhat erect; leaves very dark green, dentate. Early.

b. Flower buds yellow with no red dot.

Type 6. Plants intermediate in height, spreading; leaves somewhat light green, serrate. Very early.

Type 7. Very similar to type 6, but the plants are somewhat taller and later and the leaves lighter in colour.

II. Outer bracts ovate to rounded, moderately spinose to spineless.

1. Bracts hairy, whitish.

A. Florets yellow, not turning to red on fading.

a. Flower buds pale yellow.

Type 8. Plants intermediate in height, spreading; leaves dark green, serrate. Early.

b. Flower buds deep yellow.

Type 9. Plants tall, spreading; leaves dark green, almost spineless, serrate. Early.

B. Florets yellow, turning to red on fading.

a. Flower buds deep yellow.

Type 10. Plants tall, very erect with long almost parallel branches; leaves long, dark green, almost spineless, serrate. Late.

Type 11. Plants tall, very erect, branches shorter than in type 10; leaves dark green, spines few, serrate. Early.

Type 12. Plants rather tall, somewhat erect; leaves dark green but lighter than in type 11, serrate; early (later than type 11).

Type 13. Plants tall, erect; leaves long, light green, spines few, incised. Late.

b. Flower buds deep yellow with a trace of red near the apex.

Type 14. Plants tall, erect; leaves long, dark green, spines few, incised. Intermediate in time of maturity.

c. Flower buds deep yellow, reddish near the base.

Type 15. Plants short, spreading; leaves light green, spinose, serrate; bracts spiny. Very early.

Type 16. Plants intermediate in height, spreading; leaves light green, spines few. Intermediate in time of maturity.

d. Flower buds deep red with a yellow apical point.

Type 17. Plants tall, erect with long branches; leaves dark green, nearly spineless, incised. Late.

2. Bracts almost smooth, green, florets yellow turning to red on fading.

A. Flower buds deep yellow.

Type 18. Plants tall, branching above the ground, erect; leaves long, somewhat light green, nearly spineless, deeply incised. Late.

Type 19. Plants tall, erect, branching from the ground; leaves long, dark green, nearly spineless, incised. Very late.

Type 20. Plants short, somewhat spreading, very spinose; leaves small, very light green, serrate. Very early.

B. Flower buds deep yellow with a reddish apex.

Type 21. Plants intermediate in height, somewhat spreading; leaves somewhat light green, incised. Late.

Type 22. Plants tall, somewhat erect, leaves dark green, incised. Early.

C. Flower buds deep yellow with a reddish base.

Type 23. Plants short, spreading; leaves light green, serrate. Intermediate as regards time of maturity.

D. Flower buds deep red with a yellow apical point.

Type 24. Plants tall, erect; leaves long, somewhat light green, incisions few. Late.

Description of the Types.

I. *Outer bracts lanceolate, distinctly spinose.*

Type 1. Intermediate as regards time of flowering but very late in maturing, height 137 cm., habit erect. Leaves 17 × 5 cm., incised, dark green. *Inflorescence leaves* lanceolate, spinose-serrate with long spines. Outer *involucral bracts* leafy, constricted above the base, lanceolate, spiny (spines long); inner bracts narrower, 3 × 1 cm. *Florets* white in mature bud or when open, fading to dirty white.

Type 2. Intermediate as regards maturity, height 113 cm., habit spreading. *Leaves* 23 × 8 cm., incised, light green. *Inflorescence leaves* lanceolate, spinose-serrate with long spines. Outer *involucral bracts* leafy, constricted above the base, lanceolate with long spines; inner bracts narrower, 3 × 1 cm. *Florets* deep yellow in mature bud, yellow when open, fading to brownish yellow.

Type 3. Very early, height 118 cm., habit spreading. *Leaves* 22 × 6 cm., serrate, dark green. *Inflorescence leaves* lanceolate, spinose-serrate with long spines. Outer *involucral bracts* leafy, constricted above the base, lanceolate with long spines; inner bracts narrower, 3 × 1 cm. *Florets* deep yellow in the mature bud, yellow when open, fading to brownish yellow.

Type 4. Very early, height 93 cm., habit spreading. *Leaves* 16 × 4 cm., oblanceolate, dentate, very light green. *Inflorescence leaves* lanceolate, spinose-serrate with long spines. Outer *involucral bracts* leafy, constricted above the base, lanceolate with long spines; inner bracts narrower 2·4 × 0·7 cm. *Florets* deep yellow in the mature bud, yellow when open, fading to brownish yellow.

Type 5. Early, height 115 cm., habit spreading. *Leaves* 19 × 6 cm., oblanceolate, dentate, very dark green. *Inflorescence leaves* lanceolate, spinose-serrate with long spines. Outer *involucral bracts* leafy, constricted above the base, lanceolate with long spines; inner bracts narrower. *Florets* deep yellow in the bud with a red dot on the apex, yellow when open, fading to orange red.

Type 6. Very early, height 145 cm., habit spreading. *Leaves* 20 × 6 cm., oblanceolate, serrate, somewhat light green. *Inflorescence leaves* lanceolate, spinose-serrate with long spines. Outer *involucral bracts* leafy, constricted above the base, lanceolate with long spines; inner bracts narrower 3 × 1 cm. *Florets* deep yellow in the mature bud, yellow when open, fading to orange red.

Type 7. Early, height 133 cm., habit spreading. *Leaves* 19 × 5 cm., oblanceolate, dentate, light green. *Inflorescence leaves* lanceolate, spinose-serrate with long spines. Outer *involucral bracts* leafy, constricted above the base, lanceolate with long spines; inner bracts narrower, 4·4 × 1·1 cm. *Florets* deep yellow in the mature bud, yellow when open, fading to orange red.

II. *Outer bracts ovate to rounded, moderately spinose to spineless.*

Type 8. Early, height 117 cm., habit spreading. *Leaves* 18 × 5 cm., oblanceolate, serrate, dark green. *Inflorescence leaves* lanceolate, spinose with short spines. Outer *involucral bracts* leafy, constricted above the base, elliptical with a few short spines; inner bracts narrower, felted, 3 × 1 cm *Florets* pale yellow in the mature bud and when open, fading to a brownish tint.

Type 9. Early, height 148 cm., habit spreading. *Leaves* 21 × 5 cm., oblanceolate, serrate, dark green. *Inflorescence leaves* lanceolate, almost entire with a few very short spines. Outer *involucral bracts* leafy, constricted above the base, lanceolate to ovate, with a few short spines; inner bracts narrower, 2 × 1 cm. *Florets* deep yellow in the mature bud, yellow when open, fading to brownish yellow.

Type 10. Late, height 162 cm., habit erect. *Leaves* 25 × 7 cm., oblanceolate, serrate, dark green. *Inflorescence leaves* lanceolate, entire with occasional short spines. Outer *involucral bracts* leafy, constricted above the base, elliptical, entire with occasional short spines; inner bracts narrower, felted, 2·5 × 1·6 cm. *Florets* deep yellow in the bud and when open, fading to red.

Type 11. Early, height 145 cm., habit erect. *Leaves* 20 × 5 cm., oblanceolate, dentate, dark green. *Inflorescence leaves* lanceolate, spinose-serrate with short spines. Outer *involucral bracts* leafy, constricted above the base, elliptical, entire with occasional short spines ; inner bracts narrower, felted. *Florets* deep yellow in the mature bud, yellow when just open, fading to orange red.

Type 12. Early, height 121 cm., habit somewhat erect. *Leaves* 19 × 5 cm., oblanceolate, serrate, somewhat dark green. *Inflorescence leaves* lanceolate, almost entire with occasional short spines. Outer *involucral bracts* leafy, constricted above the base, elliptical, almost entire with occasional short spines ; inner bracts narrower, felted. *Florets* deep yellow in the mature bud, yellow when open, fading to red.

Type 13. Late, height 155 cm., habit somewhat erect. *Leaves* 23 × 5 cm., oblanceolate, incised, light green. *Inflorescence leaves* lanceolate, spinose-serrate with short spines. Outer *involucral bracts* leafy, constricted above the base, obovate to rounded, with occasional short spines ; inner bracts narrower, felted. *Florets* deep yellow in the bud, yellow when open, fading to orange red.

Type 14. Intermediate as regards time of maturity, height 152 cm., habit somewhat erect. *Leaves* 22 × 6 cm., oblanceolate, incised, dark green. *Inflorescence leaves* lanceolate, spinose-serrate with short spines. Outer *involucral bracts* leafy, constricted above the base, elliptical to rounded, almost entire with occasional short spines ; inner bracts narrower, felted. *Florets* deep yellow in the bud with a trace of red at the apex, yellow when open, fading to red.

Type 15. Early, height 99 cm., habit spreading. *Leaves* 15 × 4 cm., oblanceolate, serrate, light green. *Inflorescence leaves* lanceolate, spinose-serrate with a few short spines. Outer *involucral bracts* leafy, constricted above the base, lanceolate, spinose-serrate with numerous short spines ; inner bracts narrower, felted. *Florets* deep yellow with a red ring near the base in the mature bud, yellow when open, fading to red.

Type 16. Intermediate as regards time of maturity, height 111 cm., habit spreading. *Leaves* 18 × 5 cm., oblanceolate, serrate, light green. *Inflorescence leaves* lanceolate, spinose-serrate with a few short spines. Outer *involucral bracts* leafy, constricted above the base, lanceolate to elliptical, almost entire with occasional short spines ; inner bracts narrower, felted. *Florets* deep yellow with a red ring near the base in the mature bud, yellow when open, fading to red.

Type 17. Late, height 167 cm., habit erect. *Leaves* 30 × 8 cm., oblanceolate, incised, dark green. *Inflorescence leaves* elliptical, entire, without spines. Outer *involucral bracts* leafy, constricted above the base, elliptical, entire, without spines; inner bracts narrower, felted. *Florets* deep red with a yellow apical point in the mature bud, orange red with a little yellowness when open, fading to a deep red.

Type 18. Late, height 148 cm., habit erect. *Leaves* 28 × 6 cm., oblanceolate, deeply incised, somewhat light green. *Inflorescence leaves* lanceolate, almost entire with a few short spines. Outer *involucral bracts* leafy, constricted above the base, elliptical to lanceolate, almost entire with occasional short spines; inner bracts narrower, smooth. *Florets* deep yellow in the mature bud, yellow when open, fading to red.

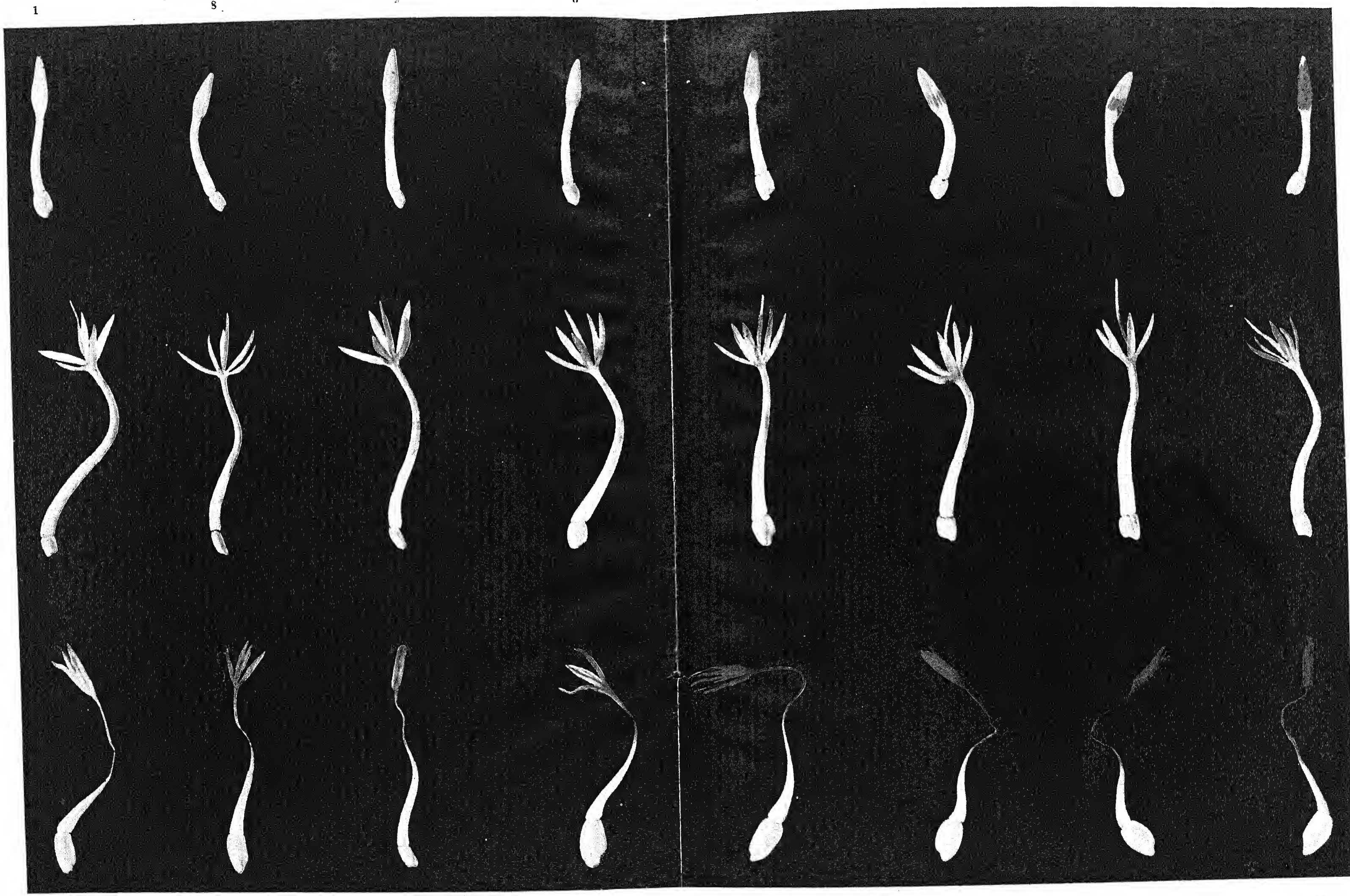
Type 19. Very late, height 168 cm., habit erect. *Leaves* 30 × 6 cm., oblanceolate, incised, dark green. *Inflorescence leaves* lanceolate with a few short spines. Outer *involucral bracts* leafy, constricted above the base, elliptical, almost entire with occasional short spines. *Florets* deep yellow in the mature bud, yellow when open, fading to red.

Type 20. Very early, height 98 cm., somewhat spreading. *Leaves* 14 × 4 cm., oblanceolate, serrate, very light green. *Inflorescence leaves* lanceolate, spinose-serrate with numerous spines. Outer *involucral bracts* leafy, constricted above the base, linear lanceolate, spinose-serrate with numerous spines; inner bracts narrower, smooth. *Florets* deep yellow in the mature bud, yellow when open, fading to red.

Type 21. Late, height 128 cm., habit spreading. *Leaves* 20 × 6 cm., oblanceolate, incised, somewhat light green. *Inflorescence leaves* lanceolate, spinose-serrate with numerous short spines. Outer *involucral bracts* leafy, constricted above the base, lanceolate, spinose-serrate with numerous spines; inner bracts narrower, smooth. *Florets* deep yellow in the mature bud with a red spot on the apex, yellow without the red spot when open, fading to red.

Type 22. Early, height 131 cm., habit somewhat erect. *Leaves* 19 × 6 cm., oblanceolate, incised, dark green. *Inflorescence leaves* lanceolate, spinose-serrate with numerous short spines. Outer *involucral bracts* leafy, constricted above the base, obovate to rounded, spinose, inner bracts narrower, smooth. *Florets* deep yellow with a red spot on the apex in the mature bud, yellow without the red spot when open, fading to red.

Type 23. Intermediate as regards time of maturity, height 105 cm., habit spreading. *Leaves* 19 × 6 cm., oblanceolate, serrate, light green. *In-*



DISTRIBUTION OF COLOUR IN SAFFLOWER FLORETS.

florescence leaves lanceolate, spinose-serrate with short spines. Outer *involucral bracts* leafy, constricted above the base, elliptical, spinose-serrate with a few short spines; inner bracts narrower, smooth. *Florets* deep yellow with a reddish base in the mature bud, yellow when open, fading to red.

Type 24. Late, height 156 cm., habit erect. *Leaves* 25 × 6 cm., oblanceolate, incised, somewhat light green. *Inflorescence leaves* lanceolate, nearly entire with a few short spines. Outer *involucral bracts* leafy, constricted above the base, elliptical with a few short spines; inner bracts narrower, smooth. *Florets* deep red with a yellow apical point in the mature bud, orange red when open, fading to a very deep red.

IV. ECONOMIC ASPECTS.

As safflower is cultivated either for the oil in the seeds or for the dye in the flowers or for both, it is interesting to compare the oil content and the colour of the faded florets in the types which have been isolated. The percentage of oil or rather the percentage of the seed extracted by ether has been determined in the Chemical Section at Pusa with the following results :—

TABLE VI.

Oil content of the types of Indian safflower.

Type	Date of appearance of first flower	Weight in grammes of 100 seeds	Percentage of oil	Colour of faded florets
1	2-3-14	6·1	13 86	Colourless
2	25-2-14	4·4	26·86	Light brown
3	16-2-14	5·6	24·12	Brown
4	14-2-14	3·9	25·60	Brown
5	23-2-14	4·5	27·26	Red
6	23-2-14	5·1	26·77	Reddish yellow
7	20-2-14.	5·0	30·19	Reddish yellow
8	23-2-14	4·2	24·00	Light brown
9	23-2-14	4·8	27·99	Brown
10	3-3-14	4·2	25·54	Red
11	23-2-14	3·2	28·19	Red
12	20-2-14	5·1	27·18	Red
13	2-3-14	4·0	24·43	Red
14	25-2-14	3·8	27·19	Red
15	20-2-14	3·1	26·42	Red
16	27-2-14	3·9	25·72	Red
17	9-3-14	3·9	28·64	Deep red
18	2-3-14	4·2	24·99	Red
19	10-3-14	2·8	28·95	Red
20	23-2-14	4·3	26·53	Red
21	23-2-14	2·9	25·46	Red
22	20-2-14	5·3	20·77	Red
23	25-2-14	3·4	28·35	Deep red
24	4-3-14	3·1	26·82	Deep red

An examination of the table shows that there is no antagonism between high oil-content and the full development of the red colouring matter as indicated by the faded florets. Oil-yielding and colour-producing capacity appear to be independent of one another. Indeed, some of the types, such as 17 and 24 which are high in oil, also develop a deep red colour in the florets. This does not necessarily mean that these types will be the best yielders. Cropping power depends on other factors in addition to the percentage of oil and the development of the red colour. The habit of the plant, the development of the root system and the time of flowering and maturity influence yield to a very great extent.

In order to obtain a definite opinion on the range in colour content of representative types, samples of flowers were prepared in the country fashion and submitted to Dr. Marsden, Tinctorial Expert to the Government of Madras. The flowers were picked before fading and afterwards pounded in a mortar with a little water. The soluble yellow substance was squeezed out and the residue pressed into a cake. These cakes were kept covered for a night, broken up and dried in the sun the next day. Twelve samples were submitted to Dr. Marsden, three of which (types 1, 8 and 9) did not develop any red colour on fading. His report, dated May 3rd 1915, was as follows :—

"I am sending to-day, dyed hanks giving the comparative strengths of the samples of safflower forwarded to me.

The method of treatment was the same in each case, a weighed quantity of the flowers being taken and extracted with water slightly acidified with acetic acid until the yellow colouring matter was almost entirely removed. As the washing proceeded, the residual flowers became bright red coloured and when the washings were but faintly coloured the extraction was continued with a measured, dilute solution of carbonate of soda. The flowers were left a dull drab colour by this extraction and hanks of bleached cotton yarn were worked in the extracts and the dyeings finished by the addition of tartaric acid.

The shades are of the same tone in general, but No. 23 and Dacca are somewhat duller and bluer than the others.

With regard to intensity of shade, I would place them in the following order—Type Nos. 24, 17, Dacca, 20, 16, 23, 10, 12, 5.

Nos. 1, 8, 9, contain no red dye. I have no tintometer with which to measure the absolute depths of shade but I estimate that type 24 is about eight times as rich in dyestuff as type 5.

With regard to the value of the dyestuff this of course is a question of taste and market demand. The shade is delicate in tone, but it is also very

sensitive and is changed so readily by various influences (alkali, acid, light) that there can be no possibility of the dye finding any application in directions in which the market demands any degree of resistance to these influences. Its properties in this respect are so poor that it possessed no chance of competing with the first synthetic dyestuff placed on the market which approximated to it in shade and now there are many which surpass it in brilliance, fastness and general utility, so that I see no hope of it ever again coming into general use. The rhodamine dyes displaced it when they were first discovered, even though they were sold at 25 to 30 shillings a pound and their price now being down to between one and two shillings, it is hopeless to think of their use being given up when the tests show that 1 lb. of say rhodamine 6·G is equal in dyeing power to 100 lb. of safflower, and the manipulation is easier."

The report brings out quite clearly the great range in colour content in the types which it would appear can be judged roughly by eye after the yellow colouring matter has been extracted. In spite of the fugitive nature of the dye, it is interesting to find that it is still used in India and has not yet been entirely displaced by synthetic products.

The chief value of the crop at the present time is undoubtedly the oil in the seeds while the colour in the flowers is only a secondary matter. Where the crop is of sufficient importance, its improvement is a comparatively simple matter. Form separation is clearly indicated as the method to be followed and once the types have been separated from the heterozygotes and studied in pure culture, all that is necessary is to compare the yields of all the likely kinds. In such work, four main points have to be considered in selecting for yield—oil-content, time of maturity, habit and colour content. The types which branch and stand well, such as Nos. 5, 6, 7, 14, 15, 16 and 19 are likely to yield better than the tall types with crowded branches. The time of flowering and the period when ripening takes place are also important. While the improvement of safflower by selection is not likely to be difficult, it will not be an easy matter to establish a superior kind on a large scale. Once a stock of pure seed has been obtained, it will be necessary to replace the country crop entirely and to carry this out on a systematic plan starting from a given centre. If this is not accomplished, natural crossing will take place and little or no permanent improvement will result from distributing seed. The improvement of a crop in India, in which natural crossing is common, is largely a matter of organization and the isolation of a better kind can only be regarded as an important step in the work.

INDIAN MUSTARD (RAI).

I. INTRODUCTION.

Indian mustard (*Brassica juncea*, H. f. & T.) is fairly extensively cultivated in the Gangetic plain, particularly in Bengal and Bihar. In the United Provinces and the Punjab, mustard gives place to rape (*tori* or *toria*). According to Duthie and Fuller,[1] mustard is rarely grown alone in the United Provinces but is subordinate to wheat, barley and peas and is usually restricted to the borders of fields. Watt[2] states that mustard yields less oil than rape (one-fourth instead of one-third) to the weight of seed and that the oil is less esteemed as an article of food. The seed is very generally used in India as a spice to give flavour to vegetables and sometimes also as a medicine.

The area under this crop in India is not given separately in the *Agricultural Statistics of India* but is included with colza (*sarson*) and rape as "rape and mustard." The export of mustard, however, is given separately and, in 1912-13, amounted to 73,058 cwt.[3]

In 1909, a beginning was made at Pusa in the study of the oil seed crops of India belonging to the genus *Brassica*. For this purpose, 144 samples of seed of these crops, which had been collected from various parts of India, were sown at Pusa. In nearly all cases, the samples were mixtures of varying proportions of mustard, colza and rape. As it was not possible to deal simultaneously with all the forms of these three species which appeared in the cultures, type separation was limited to the mustard crop. Self-fertilized seed of three hundred and ninety-eight single plants of *rai* was obtained at the harvests of 1909 and 1910. Many of the plants, however, proved to be heterozygotes and most of these splitting cultures were rejected. In 1914, one hundred and two distinct types, which bred true, remained. These 102 pure lines, which are all quite distinct in the field, form the material on which our study

[1] Duthie and Fuller, *Field and Garden Crops of the North-Western Provinces and Oudh*, vol. II, 1883, p. 33.

[2] Watt, *Commercial Products of India*, 1908, p. 181.

[3] *Annual Statement of the Sea-borne Trade and Navigation of British India*, vol. I, 1913, p. 685.

of Indian mustard is based. As the original seed was collected from a wide area and as many as 398 single plants were originally selected in 1910, it is evident that the Pusa cultures can be taken to represent adequately the botanical constitution of this crop.

The botanical aspect of the various oil seeds of Bengal and Bihar, belonging to the genus *Brassica*, has been studied in detail by Prain[1] and the results naturally form the beginning of any further work on these crops. He sums up his account as follows :—

"As regards the relationship that our three staple mustard-oil crops bear to the corresponding crops in Europe, it may be tentatively held :—

(1) that *rai* (*Brassica juncea*) is a crop not grown in Europe, at any rate on a commercial scale, but that it takes the place here of *Brassica nigra* and *Brassica alba*, which in turn are not grown in India ;

(2) that *sarson* (*Brassica campestris* var. *sarson*) is a crop not grown largely, if at all, in Europe, but that in India it takes the place both of *Brassica compestris* var. *oleifera* and *Brassica Rapa* var. *oleifera*, which in turn are hardly ever met with here.

(3) that *tori* (*Brassica Napus* var. *dichotoma*) seems to be the same plant as *Brassica præcox* (summer rape) or if not the same is at least very like and very near it and is undoubtedly the plant that in India takes the place of *Brassica præcox* and of *Brassica Napus* var. *oleifera*."

Prain concludes that *rai* or Indian mustard is the most important of the three species of *Brassica* grown in Bengal and Bihar, and is met with everywhere " except in Chota Nagpur where it is practically unknown. It is easily recognised by having none of its leaves stem-clasping, and, after reaping, its seeds, which are brown, can be readily distinguished from those of *tori*, or Indian rape, by their smaller size, their being distinctly rugose, and being reddish brown all over. From *sarson*, which has white seeds or, less often in Bengal, brown seeds, it is equally easily distinguished ; *sarson* seeds are always considerably, often very much larger, and even when brown have the seed coats smooth.

There are three sub-races, a tall, late kind, and two shorter earlier kinds, one of these latter with bristly hairs, the other smooth with darker coloured stems."

[1] Prain, *The Agricultural Ledger*, vol. V, 1901, p 1.

II. BIOLOGY OF THE FLOWER.

FLOWERING.

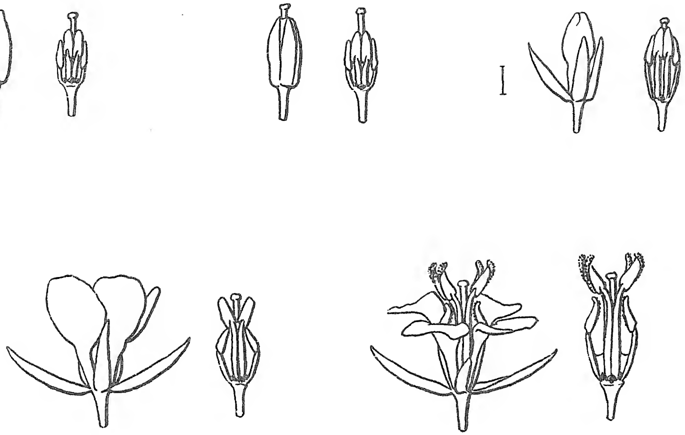
At first, the flowers form short corymbs about 2·5 cm. long when the lowest flower opens after which the inflorescence elongates into a raceme from 20 to 80 cm. in length. The flowers are borne on pedicels, each from 0·4 to 1·4 cm. long, which are without bracts or bracteoles. As the fruit ripens, the stalks slightly increase in length.

The total flowering period varies considerably according to the earliness or lateness of the type. The onset of the hot winds at once terminates the flowering of all late forms but does not affect the early kinds as these have ripened most of their seed before the hot weather begins. Observations, made in 1915 on 21 types, showed that the flowering period varied from 43 to 64 days. The earliest type commenced to flower on November 10th, 1914 and the latest on January 2nd, 1915.

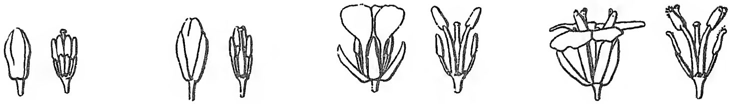
The flowers of the racemes open in acropetal succession. As a rule, two to four flowers are open at once on each raceme and when the plants are in full bloom each may carry as many as ten open flowers at the same time. Most of the flowers begin to open from 9 A.M. to 12 noon, but some partly open up to 4 P.M. and a few before 9 A.M. They remain open for three days, fading gradually every day and on the fourth day the petals and sepals are shed.

POLLINATION.

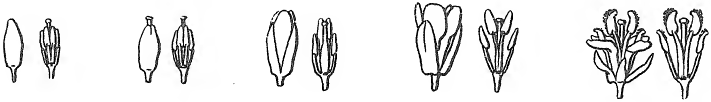
In the bud stage, the immature stamens are always below the stigma. Before the flower opens, the style often increases in length and the sepals and petals expand just sufficiently to produce a small opening at the apex through which the stigma is extruded into the air to a distance of 2 mm. As a rule, the extrusion of the stigma takes place in the evening, and all such flowers invariably open the next morning about 9 A.M. The length of style extruded varies a great deal even in the same plant but in many cases the stigma does not grow out into the air but remains flush with the opening of the tube formed by the corolla. Observations on December 18th, 1914 showed that out of 36 flowers which opened the next day, 18 showed extruded stigmas the previous evening. The stigmas are receptive as soon as they reach the outer air. Soon after the extrusion of the stigma, two other changes take place—the sepals begin to open and the corolla and stamens begin to grow. The increase in length of the corolla is so rapid that it soon grows past the stigma and this latter disappears again before the flower opens the next morning. Just before opening, the filaments have carried the anthers almost



Indian Rai (Type 60.)



Mohari.



Burmese Rai (Type 103.)

FLOWERING DETAILS IN RAI AND MOHARI.

up to the stigma (Plate III). Soon after the corolla opens, the filaments of the long stamens turn half round so that the pollen-covered surfaces of their burst anthers are turned towards the adjacent short stamens which have their pollen surfaces directed towards the style (Fig. 1.) At this period, the

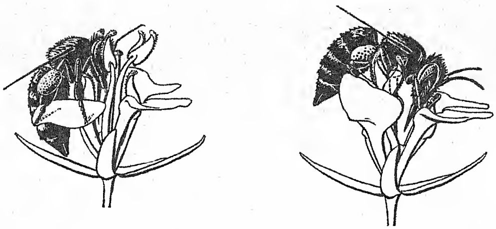


Fig. 1. Pollination by bees.

nectar is secreted, particularly by the pair of nectaries on the inner side of the bases of the short stamens. Large bees in great numbers visit the flowers soon after they are open. These insects, in searching for honey, always deal with one side of the flower first and insert themselves between the burst long and short stamens. The short stamen touches the under side of the thorax while the long stamens touch the bee's head and the stigma at the same time. The bee then passes over the stigma to visit the nectary on the other side and again comes between the other set of burst anthers touching the stigma again with the pollen-covered thorax. These arrangements are obviously effective in promoting pollination and it is clear that a certain amount of crossing is to be expected. The small bees which visit the flowers for the nectar do not act in the above manner but take nectar from the side direct without passing over the stigma. All pollen-gathering bees, however, move over the stigma and so bring about pollination. In the absence of insect visitors, pollination is effected by the long stamens, the upper portion of the anthers of which bends towards the stigma so that any slight shaking of the flower by wind is sufficient to accomplish the transfer of pollen. This is confirmed by the fact that the flowers set normally under bag or under nets without any difficulty.

Natural cross-fertilization.

Large series of *rai* cultures have, on two occasions, been grown at Pusa primarily for the purpose of form separation. These cultures also afford evidence as to the occurrence of heterozygotes in the ordinary crop.

In 1909, 82 different single plants were sown. Of these, 55 bred true and 27 gave rise to mixed cultures. Seventeen plants split with regard to the close or open arrangement of the pods[1] while 10 split into tall and short plants.

In 1910, 316 additional single plants were selected from the produce of seed collected from many parts of India. In every case, the seed of these 316 plants was raised under bag so that no crossing took place at Pusa and any heterozygotes must have been produced in the districts. An examination of these cultures showed that 174 were mixed while 142, or nearly 45 per cent., bred true. An examination of the cultures, which were not uniform, showed that splitting took place in many directions such as hairy and smooth leaves, spreading and appressed pods, late and early ripening and tallness and shortness. Thus out of a total number of 398 single plant cultures grown at Pusa, no less than 197 or 49·5 per cent. bred true. These figures indicate that crossing is not so common in *rai* as would be expected judging only from the structure of the flower and from the method of pollination. It is clear that in a selection such as this, primarily intended for form separation in which every type is isolated, the results do not give any true idea of the proportion of natural crosses in the country crop. The method would favour the selection of heterozygotes as it includes every plant which appears a little different from the rest.

In 1915, the seed of five types, obtained from free-flowering plants growing side by side, was sown and the resulting cultures examined for heterozygotes. The results (Table VII) give a fair idea of the amount of crossing which takes place in any year when different types are grown in lines next to next and when no precautions are taken to exclude the visits of insects.

TABLE VII.

Crossing in rai at Pusa in 1914.

Type	Total number of plants	Number of heterozygotes	Percentage of crossing
7	307	23	7·5
17	235	20	8·5
83	241	45	18·7
91	71	24	33·8
226 D	213	39	18·3
Total	1,067	151	Average 14·1

These results show that in *rai* self-pollination is the rule and that cross-pollination takes place to some extent. A study of the country crop shows

[1] *Mem. Dept. Agr. in India (Botanical Series)*, vol. III, 1910, p. 318.

that while heterozygotes occur, a large proportion of the crop breeds true. When pure lines are grown next to next and allowed to cross, the Pusa results of 1915 show that about 15 per cent. of crossing takes place in any one year when a very large number of types are grown next to next in lines. In the field, the proportion of heterozygotes produced in any year would naturally be far fewer than 15 per cent. as the opportunities for crossing between different types would be much less. These results agree with the experience of von Rümker,[1] in the case of rape at Breslau, who states that in this crop self-fertilization is the rule while cross-fertilization is possible.

As would be expected from the predominance of self-fertilization in *rai*, the continued propagation of the types from seed obtained from protected flowers leads to no apparent loss of vigour. In 1914-15, a careful comparison was made between plants raised from bagged and unbagged seed in the case of four types. The cultures were grown next to next and no differences in size or in vigour of growth could be detected.

Hybridization.

All the various types of Indian mustard cross freely among each other and also with the forms isolated from Burma mustard mentioned on page 268. Some crosses between various types have been carried to the second generation when the following results were obtained.

(1) When tall and short types are crossed, the F_1 generation is in some cases taller than the tall parent, while in other cases it is intermediate, as will be seen in Table VIII in which the results of 1913-14 are shown.

Table VIII.

The inheritance of height in rai.

Parents	Height in feet	F_1	Height in feet
Parent—Type 4 Parent—Burma 226 D	5·5 4·3	F_1 Type 4 × Burma 226 D	6
Parent—Type 4 Parent—Burma 218	5·5 5·8	F_1 Type 4 × Burma 218	6·1
Parent—Type 39 Parent—Burma 226 D	5·5 4·1	F_1 Type 39 × Burma 226 D	6·0
Parent—Type 39 Parent—Burma 218	5·4 5·9	F_1 Type 39 × Burma 218	6·2
Parent—Type 102 Parent—Burma 226 D	8·9 4·4	F_1 Type 102 × Burma 226 D	7·0
Parent—Type 102 Parent—Burma 218	9·5 5·9	F_1 Type 102 × Burma 218	8·0

[1] *Zeit. f. Pflanzenzüchtung*, I, 327. 1913.

In the first four crosses the F_1 is taller than the taller parent while in the last two it is intermediate.

(2) When types with close and spreading pods are crossed, the progeny shows that the close arrangement is prevailing.

(3) When Indian mustards with divided leaves are crossed with the Burma forms with entire leaves, the F_1 is intermediate while a series is obtained in the F_2 (Plate IV).

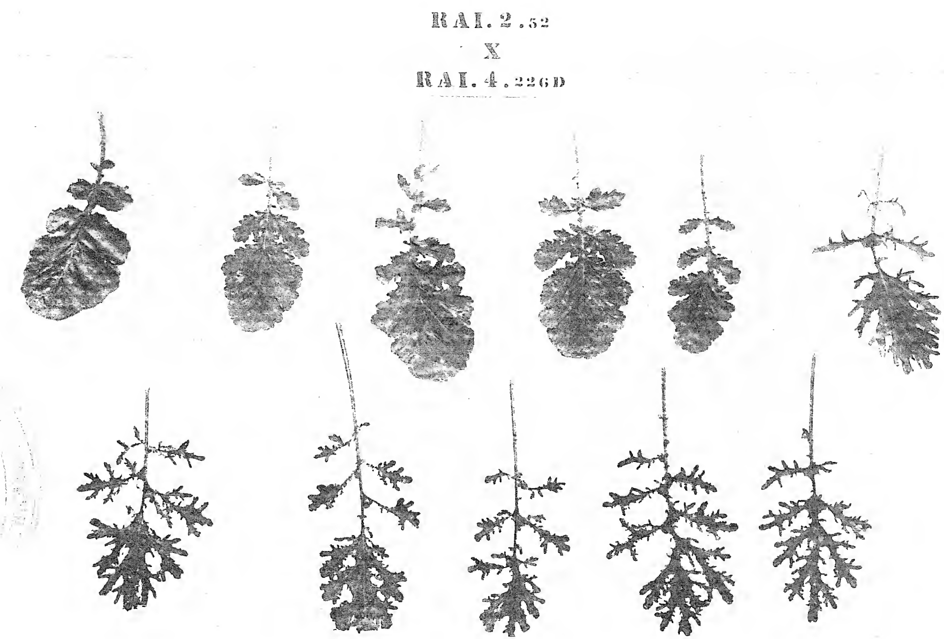
(4) When late and early forms are crossed, the F_1 is intermediate.

III. FORM SEPARATION.

The forms of Indian *rai* so far studied agree with the following general description of the crop which has been adapted from Prain's account :

A cold weather crop in the plains of India of tall, annual, much-branched or spreading herbs from 90 to 285 cm. high and 45 to 110 cm. across. *Root* slender, tapering, 15 to 35 cm. long. *Leaves* large, the blades of the basal from 15 to 48 cm. long, 8 to 20 cm. wide, sinuate-lyrate, tapering to a stalk 2·5 to 8 cm. long, decreasing upwards ; upper leaves small, narrow, sessile, entire with a slight development of bloom on the under surface. *Stem* branching from the fourth or fifth leaf upwards, all branches about as long as the continued main stem and often again branching, usually more or less tinged with purple, especially near the joints. *Flowers* in short corymbs about 2·5 cm. long when the first flower opens, subsequently elongating into a raceme 20 to 80 cm. long with nearly equal slender pedicels 0·5 to 1·5 cm. long, without bracts or bracteoles, either spreading or appressed to the stem. *Sepals* slightly spreading, 0·5 to 0·75 cm. long, 0·1 to 0·15 cm. wide, green, turning yellowish before falling. *Corolla* 1·2 to 1·8 cm. across ; petals with a pale green narrow claw 0·25 to 0·35 cm. long and a bright yellow, spreading, regularly obovoid blade 0·6 to 0·8 cm. long, 0·5 to 0·75 cm. across. *Pods* 2-valved, flat, including the beak 3·5 to 5 cm. long, 0·3 to 0·5 cm. wide, beak narrowly conical 0·7 to 1·0 cm. long ; valves convex, rigid, thinly leathery, distinctly beaded opposite the seeds, with a straight strong midrib, prominent outside, with rather strong prominent looped veins on each half valve. *Seeds* about 10 under each valve, spherical, brown, finely rugose ; hilum the colour of the remainder of the testa ; cotyledons yellow.

The size to which *rai* attains in India depends among other factors on the soil temperature. At Pusa, in seasons when the *hathia* rains fail in October



THE RANGE IN LEAF FORM IN THE SECOND GENERATION.

Type 1. Type 39. Type 103 (Burma.) Mohari.

THE POSITION OF THE PODS IN RAI AND MOHARI.

and when sowing is carried out at the ordinary time in the warm soil, it is observed that the crop does not remain long in the vegetative condition but commences to shoot prematurely and to flower early. The yield of seed under such conditions is low. This abnormal development in such seasons can to some extent be prevented by cooling the soil by cultivation in October and by late sowing. Similar abnormal growth is seen in crops like yellow-flowered tobacco (*N. rustica*) and *sarson* if they are sown too early and before the ground has cooled sufficiently. One of the chief uses of the *hathia* rains in Bihar appears to be to cool the country low enough for the cold weather crops to thrive.

The 102 types of Indian mustard offer no great difficulty in classification provided this is based both on morphological and on field characters. Up to the division of the types into main groups, the classification follows the usual lines. The precise distinction between the types however can only be fully appreciated in the field when they are grown in lines, next to next, under uniform conditions. In this way, what may be called the massed habit comes into play and the small differences in the mode of branching, in the size and tone of colour of the leaves and in the time of ripening become added together and serve to distinguish the various forms. In herbarium specimens, these distinctions would be lost. The labour of reducing them to paper is so great that no effort has been made to accomplish this exceedingly difficult task. Before giving the actual classification, some reference is necessary to the most important characters on which it is based.

Position of the pods. In the majority of the types, the ripe pods stand at an angle of about 50° from the axis of the inflorescence and in these cases the pods can be described as spreading. In a few cases, however, and these do not seem to have been observed by Prain, the pedicels when ripe stand much closer to the axis at a general angle of from 5° to 10°. In these cases the pods are distinctly appressed. The position of the pods in the various types is very constant from year to year so that this character can be safely used in classification (Plate V).

Hairs on the leaves. In the seedling stage, all the types have some hairs on the first leaves but the range between the hairy forms and those which are nearly smooth is very great. As growth proceeds and the full sized leaves are developed, these differences increase and when the plants have attained their full development, the distinction between the hairy leaved and smooth leaved types is well-marked.

Mode of branching. The angle at which the secondary branches arise varies considerably between the various types and is a definite character. This expresses itself also in the breadth of the full-grown plant and, provided the land on which the types are grown is uniform and provided the measurements are all taken at the stage when the plants are fully grown, the breadth measurements would express the general mode of branching. After the seeds begin to form, the plants bend over with the weight of the developing pods and this character then becomes less easily observed.

Height. The height to which the types attain is very constant from year to year and this character is therefore of great use in the classification. It can most easily be measured by uprooting the ripe plants and measuring them with the roots upward. Height is generally correlated with time of flowering. The tall plants are always late while the dwarf types are always early.

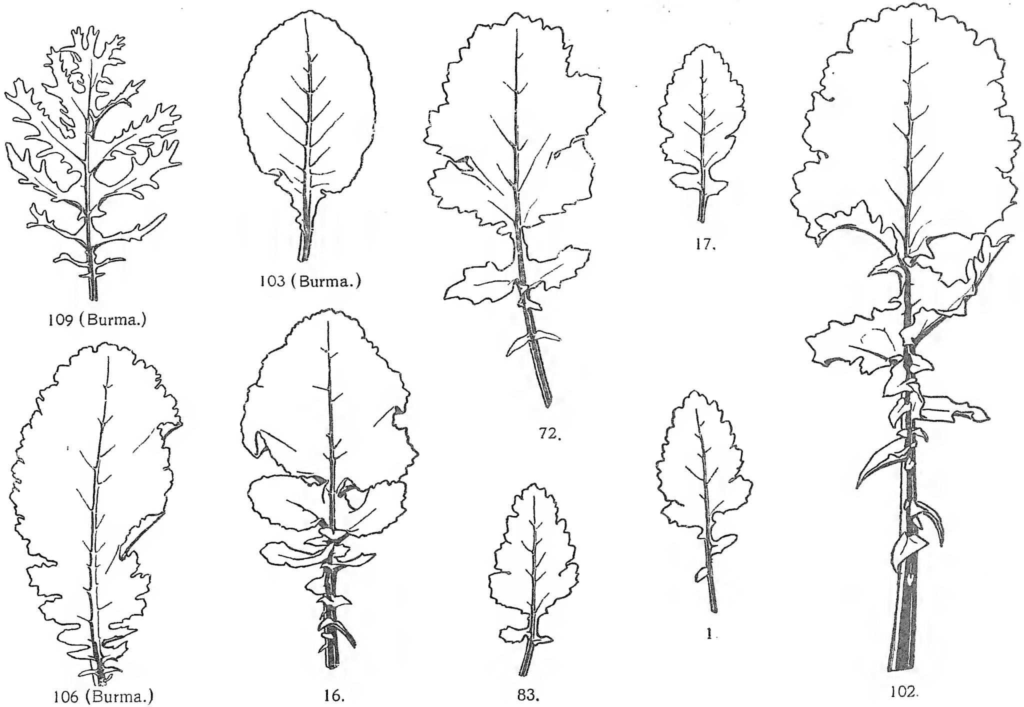
Growth period. The length of time between sowing and ripening is difficult to determine in Bihar as the onset of the hot weather is often so rapid that all late plants are dried up and normal ripening is then impossible. An accurate indication of the growth period is obtained, however, by the determination of the time when the first flower opens. This is earliest in the case of the rapidly maturing types and progressively later for the tall later kinds.

Leaf characters. The types differ considerably among themselves in details relating to the size, colour, and degree of division of the leaves. These differences come out in the massed habit and help to distinguish the types in the field, but they almost defy description and could only be adequately dealt with by actual drawings or photographs (Plate VI.).

The various types of *rai* which have been studied can be classified as follows :—

I. Pods appressed to the stem.
   1. Upper leaves distinctly hairy.
      Types 1 to 6.
   2. Upper leaves smooth or nearly so.
      Types 7 to 16.

II. Pods spreading.
   1. Upper leaves distinctly hairy.
      Types 17 to 69.
   2. Upper leaves smooth or nearly so.
      Types 70 to 102.



THE RANGE IN LEAF FORM IN RAI.

The details relating to the place of origin, the vernacular or other name of the mixtures from which the types were isolated, the height and the time of flowering are given in the tables below. In cases where the type occurred as a stray plant in a mixture this fact is indicated.

Pods appressed to the stem ; upper leaves distinctly hairy.

Type	Place of origin	Vernacular name	Height in feet in 1914	Time of flowering
1	Bhagalpur	*Rai Benari* (stray)	3·75	Early
2	Maidapur (Darbhanga)	*Rai* (stray)	4·5	,,
3	Pusa	,,	5·75	,,
4	,,	,,	6	,,
5	,,	,,	5·75	,,
6	,,	,,	4·75	Intermediate

Pods appressed to the stem ; upper leaves smooth or nearly so.

Type	Place of origin	Vernacular name	Height in feet in 1914	Time of flowering
7	Pusa	*Sarson* (stray)	3·75	Early
8	,,	*Rai*	4·5	,,
9	Shankarpur	,,	5·5	,,
10	,,	,,	4 5	,,
11	,,	,,	5	,,
12	,,	,,	5·25	,,
13	Pusa	,,	4·5	,,
14	,,	,,	5	,,
15	,,	,,	3·5	Intermediate
16	,,	,,	5·5	,,

Pods spreading ; upper leaves smooth or nearly so.

Type	Place of origin	Vernacular name	Height in feet in 1914	Time of flowering
17	Maidapur (Darbhanga)	*Rai*	3·5	Very early
18	,,	,,	3·75	,,
19	Dacca	Black *sarson*	3·5	,,
20	Patna	*Sarisha*	4·25	,,
21	Ranchi	*Latni*	3·75	,,
22	Pusa	*Rai*	5 25	,,
23	Semaria Ghat	*Rainchi*	4·75	,,
24	Patna	*Rai*	4 25	,,
25	Semaria Ghat	*Rainchi*	4·5	,,

Pods spreading; upper leaves smooth or nearly so.

Type	Place of origin	Vernacular name	Height in feet in 1914	Time of flowering
26	Allahabad	*Lahi*	3·75	Very early
27	,,	*Sarson*	4·5	Early
28	Sultanpur	*Rai*	4·5	,,
29	,,	,,	5·5	,,
30	Benares	,,	5·75	,,
31	Hamirpur	*Lahi*	6·5	,,
32	Fatehpur	,,	6	,,
33	Maidapur (Darbhanga)	*Rai*	5·75	,,
34	Shahabad	*Lalka tori*	6	,,
35	Dumraon	Jubbulpur mustard	5·75	Intermediate
36	Pusa	*Rai*	5·5	,,
37	,,	,,	6	,,
38	,,	,,	5	,,
39	Bhagalpur	*Rai Benari*	5·25	,,
40	Dumraon	Jubbulpur mustard	7	,,
41	Kheri	*Lahi*	4·75	,,
42	Fatehgarh	,,	6·75	,,
43	,,	,,	5·75	,,
44	Pusa	*Rai*	6	Late
45	,,	,,	7·25	,,
46	,,	,,	6·5	,,
47	,,	,,	6·75	,,
48	,,	,,	6·25	,,
49	Sultanpur	,,	6	,,
50	Agra	*Lahi*	6·25	,,
51	Hyderabad	*Rai*	6·75	,,
52	Mirpur-khas	Rape	8	,,
53	Dumraon	Raipur mustard	7·25	,,
54	,,	Jubbulpur mustard	8·25	,,
55	Fatehgarh	*Lahi*	7	,,
56	Hamirpur	,,	7·25	,,
57	Delhi	Black *sarson* (stray)		,,

Pods spreading ; upper leaves smooth or nearly so.

Type	Place of origin	Vernacular name	Height in feet in 1914	Time of flowering
58	Shahabad	*Lalka tori*	7·25	Late
59	Dacca	Indian rape	7·35	,,
60	Meerut	Black *sarson*	6·5	,,
61	Mirpur-khas	Mustard	6·5	,,
62	,,	,,	7·5	,,
63	Dumraon	Raipur mustard	7	,,
64	Aligarh	*Lahi*	6	,,
65	Hoshangabad	*Rai*	6	,,
66	Ahmednagar	*Mohari*	7·75	,,
67	Meerut	*Kali sarson*	7·5	,,
68	Aligarh	*Lahi*	8	,,
69	,,	*Kali sarson*	7	,,

Pods spreading ; upper leaves distinctly hairy.

Type	Place of origin	Vernacular name	Height in feet in 1914	Time of flowering
70	Ranchi	*Taramira* (stray)	2·5	Very early
71	,,	,, ,,	2·75	,,
72	Hooghly	*Lahi*	3·75	,,
73	Ballia	,,	3·5	,,
74	Pusa	*Rai*	3·75	,,
75	Basti	,,	4·25	,,
76	Allahabad	Red *sarson*	4	,,
77	Pusa	*Rai*	4·5	Early
78	,,	,,	4·5	,,
79	,,	,,	4·75	,,
80	,,	,,	4·25	,,
81	,,	,,	5·25	,,
82	,,	,,	4·5	,,
83	Kheri	*Lahi*	5	,,
84	Pusa	*Rai*	4·75	,,
85	Patna	,,	5	Intermediate
86	Benares	,,	5·5	,,
87	Fatehpur	*Lahi*	5·25	,,

Pods spreading; upper leaves distinctly hairy.

Type	Place of origin	Vernacular name	Height in feet in 1914	Time of flowering
88	Maidapur (Darbhanga)	*Rai*	5·75	Intermediate
89	Delhi	Black *sarson* (stray)	7	,,
90	Fatehgarh	*Lahi*	5·75	,,
91	Allahabad	*Sarson*	6	,,
92	Bhagalpur	*Rai Benari*	6	,,
93	Pusa	*Tori* (stray)	5·75	Late
94	,,	*Rai*	6	,,
95	,,	,,	6·25	,,
96	Kheri	*Lahi*	6·25	,,
97	Ahmednagar	*Mohari*	7	,,
98	Aligarh	*Kali sarson*	7	,,
99	Dumraon	Jubbulpur mustard	6	,,
100	North Arcot	Mustard	6·25	,,
101	,, ,,	,,	7	,,
102	,, ,,	,,	9·5	,,

Burma Mustard.

In a single sample of seed from Burma, described as mustard, a good many single plant selections were made, all of which gave mixed offspring. As these however set seed readily under bag, thirteen cultures breeding true (Types 103 to 115) were obtained in 1914. These cultures exhibit a great range as regards leaf form. In some, the lower leaves are entire, while in others, they are much divided and do not resemble any ordinary Indian forms of *rai, tori,* or *sarson.* The leaves also have a slight amount of bloom and a few hairs.

These Burmese forms cross readily with the various types of Indian mustard. In one case, where a very deeply divided Burmese type was crossed with type 60, the leaves in the F_1 were intermediate while, in the F_2, a great range was obtained which is represented in Plate IV.

The occurrence of these Burmese forms, with their curiously divided leaves, suggests the existence of oil seeds related to Indian *rai* which so far have not been described. The forms occurring in Burma are probably related to the oil-seeds of China.

MOHARI.

While the work of form-separation in *rai* was in progress, a number of cultures of a somewhat similar plant were studied. These were obtained from seed described as *mohari*, from several places in Bombay, and as *asl rai* and *Multani rai* from Delhi and Amritsar. The seed is smaller and more pungent than that of *rai* and is said to be used in many parts of India for pickling purposes under the name of *asl rai*.

The plant appears to be an early form of *Brassica nigra*, Koch. The flowers of *mohari* are self-sterile so that the crop consists of a mass of heterozygotes in which form separation is impossible.

So far, all attempts to raise seed by crossing *mohari* with *rai* pollen and *rai* with *mohari* pollen have failed.

IV. SOME ECONOMIC ASPECTS.

In the present state of our knowledge of the mustard crop in India, it is clear that the only line of improvement worth striving for lies in the increase of the yield of seed. Questions of quality do not seem to arise and there are no indications in the literature which would lead one to suppose that any one form of *rai* is better than another either for local consumption or for the export trade.

The numerous types of *rai*, isolated at Pusa, differ very greatly from one another, both in time of ripening, in size, and in yielding power. There is every gradation between the dwarf, early-maturing forms and the taller robust kinds, characterized by greater yielding power. This great variety of form, obviously suited to a wide range of conditions, indicates that methods of form-separation or selection are the most likely to yield results of value in the work of improving the crop. Nothing would appear to be gained by hybridization until the great possibilities in selection have been completely exhausted. In this respect, *rai* is no exception to the rule. In the case of practically every crop in India, a botanical survey of the existing forms, accompanied by suitable methods of form-separation, should always precede any hybridization work. It is only where selection has failed to yield the desired improvement and where a type has to be synthesized for a particular purpose that hybridization becomes essential. In *rai*, a certain amount of natural crossing is constantly taking place in the field between the various forms leading to fresh combinations of factors. If, therefore, the selection work is

carried out on a sufficiently broad basis, the new types produced are almost certain to be secured in the process of form-separation.

As the flowering period in *rai* is somewhat short, the question naturally arises whether a single pure line, however excellent, is better in the long run than a judicious artificial mixture of types, the combined flowering period of which is longer than that of the pure line. Besides the insurance against the weather afforded by extending the flowering period, a mixture of types would appear to have two other advantages. Crossing would take place between the forms leading, in many cases, to increased size and vigour. In addition, a mixture of forms of slightly different habit might fill up the available space, both as regards the range of the root system and as regards the above ground portion of the crop, to greater advantage than a pure line. This is a matter for further experiment but it is obviously one which should be kept in mind particularly in those Indian crops where no question of quality is involved and where yield is the chief consideration.

The seed supply in improved crops like *rai*, where the seed is not particularly valuable, and where natural crossing takes place is a matter of some importance to an Agricultural Department. Each plant sets a relatively small quantity of seed and it is impossible in practice, on account of cost, to protect the seed crop on the large scale from foreign pollen. Total replacement of the existing crop in any area by an improved kind or by an improved mixture is obviously the only line of progress. For this to be effective, it is clear that there must be a central farm, producing a large bulk of seed every year, together with an efficient agency, working among the people, with this farm as a centre. In the absence of these arrangements, no real economic results are likely and it is questionable whether the preliminary work of improvement, in such crops as Indian mustard, is worth while unless the means of pushing the work to its natural conclusion in the villages are certain to be available.

In the case of *rai*, the replacement of the country crop by a superior variety will have to contend with difficulties apart from the question of central seed farms and an efficient organization in the Districts. These difficulties are concerned with self-sown seed and with the fact that the seeds of *rai* remain for a long time in the ground in a viable condition and germinate, a few at a time, every year. The land becomes self-sown with *rai*, not only on account of the splitting of the pods at harvest time, but also on account of the shedding of whole fruits in the case of these types where the pods are

closely appressed to the stem (Fig. 2). There is a very good example in the Botanical area at Pusa of land self-sown with *rai*. Four years ago, a plot of

Fig. 2. Shedding of pods in *rai* (Type 1).

wheat with weak straw was sown with *rai* to ascertain whether the standing power of the wheat would be improved. At harvest time, a certain amount of the *rai* seed was shed. These seeds are brought near the surface again at sowing time in cultivation and every year a considerable number germinate in October and have to be removed. After four years, the number shows no diminution. In areas which grow a good deal of *rai*, similar self-seeding is almost certain to be taking place continually. If, therefore, an attempt is made to replace the *rai* crop by a better type in such areas, it will be

impossible to keep the new kind pure even if the country crop is replaced systematically by pure seed from a central farm. The new variety will be immediately contaminated by the self-sown seed of the original crop and complete replacement would be the work of years.

Variety trials in *rai* on a field scale are not easy and are only possible at a well-equipped station. The contamination of the cultures through vicinism is bound to take place and seed raised from such plots cannot be used again with safety. Such trials therefore involve the production of self-fertilized seed in large quantities. Shedding of seed readily takes place at harvest so that reaping has to be carried out just before the plots are ripe. This involves the keeping separate and the safe storage of the different plots for some days during the drying process, a matter of some difficulty in the case of a bulky crop like *rai.*

QUETTA,
June 23, 1915.

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MEMOIRS OF THE DEPARTMENT OF AGRICULTURE IN INDIA

ON THE INHERITANCE OF SOME CHARACTERS IN WHEAT, II

BY

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THE investigations, described in this paper, form a continuation of the earlier results on this subject published in 1912.[1] Two characters only are dealt with, bearding and felting. For the sake of clearness, the preliminary results on bearding, which appeared in the former paper, have been shortly recapitulated.

I. THE PRESENCE AND ABSENCE OF AWNS.

A study of the literature on the inheritance of awns in wheat is rendered somewhat difficult by the fact that previous investigators have not worked with comparable material. They have not used, in all cases, true beardless wheats for the analysis of the fully bearded character. Wheats with short awns as well as those absolutely beardless have been described and employed as "beardless" parents. It is hardly surprising that, under these circumstances, the results have varied and that some controversy has arisen.

The earlier results are summed up by von Tschermak in *Die Züchtung der landwirtschaftlichen Kulturpflanzen*. Biffen, Wilson, Schribaux and von Tschermak found that the beardless condition was dominant and that the F_2 generation was composed of bearded and beardless plants in the simple ratio 3 : 1. In some cases, the ratio fully bearded to half bearded and beardless in this generation was 1 : 2 : 1. Nilsson-Ehle found, however, that the beardless condition was not absolutely dominant. Von Tschermak

[1] *Mem. Dept. Agr. in India (Botanical Series)*, vol. V, no. 1, 1912.

observed in two cases, in crossing a bearded and beardless wheat, that the bearded condition was entirely lost, while Rimpau and Spielmann, on crossing two beardless wheats, obtained in the F_2 a few bearded forms which bred true. Saunders[1] in 1906 combated the statement that the first generation between a beardless and a bearded wheat is always beardless and maintained that the amount of bearding in the F_1 varies with the wheats used. In the F_2, a series of forms, which defied classification, was obtained. Apparently the subject was not followed any further.

In our investigations at Pusa with Indian wheats, the inheritance of the fully bearded character has not been simple. In crosses between bearded and what are usually described as beardless wheats, two very distinct phenomena have been observed. In one series, the plants in the F_1 were distinctly intermediate and were half bearded, while in the other only very short tips to the glumes occurred. These differences in the F_1 were correlated with differences in the beardless parents. In the first case, the beardless parent had short tips to the glumes while in the second it was absolutely beardless. In the following, these two classes are dealt with separately.

Bearded × Tipped. The half bearded F_1 generation occurred in four crosses between bearded and beardless wheats and the results (Plate I) differ entirely from those illustrated by Biffen and Wilson in vol. 1 of the *Journal of Agricultural Science.* The four crosses with an intermediate F_1 all broke up in the F_2 into fully bearded, half bearded like the F_1 and plants with tipped glumes in the ratio 1 : 2 : 1. There was no difficulty in distinguishing these classes which were very distinct the one from the other. The details relating to the 2,836 F_2 plants of these four crosses are given in the following table :—

TABLE I.

The F_2 generation of crosses between bearded and tipped parents.

Cross		No. of Plants	F_2 Generation			Ratio
			Bearded	Inter-mediate	Tipped	
BXI 77 ♀ × HI2 ♂	(1)	194	47	105	42	1·1 : 2·5 : 1
,, ,,	(2)	227	67	113	47	1·4 : 2·4 : 1
,, ,,	(3)	233	52	116	65	·8 : 1·8 : 1
HI2 ♀ × BXI 77 ♂	(5)	253	62	123	68	·9 : 1·8 : 1
TOTAL		907	228	457	222	1 : 2·1 : 1
Expectation			*226·75*	*453·5*	*226·75*	

[1] Saunders, *Report of the Third International Conference, 1906, on Genetics,* London, 1907, p. 370.

TABLE I.—(*contd*).

The F_2 generation of crosses between bearded and tipped parents.

Cross		No. of Plants	F_2 Generation			Ratio
			Bearded	Inter-mediate	Tipped	
Punjab Type 9 (*a*) ♀ × HI1 ♂	(1)	137	35	71	31	1·1 : 2·3 : 1
,, ,,	(2)	190	54	89	47	1·1 : 1·9 : 1
,, ,,	(3)	185	46	87	52	·9 : 1·7 : 1
,, ,,	(4)	117	32	55	30	1·1 : 1·8 : 1
HI1 ♀ × Punjab Type 9 (*a*) ♂	(5)	175	48	89	38	1·3 : 2·3 : 1
TOTAL		804	215	391	198	1·1 : 2·0 : 1
Expectation			*201*	*402*	*201*	
Punjab Type 9 ♀ × Punjab Type 25 ♂		1,022	244	528	250	1 : 2·1 : 1
Expectation			*255·5*	*511*	*255·5*	
American Club ♀ × Pusa 6 ♂	(1)	133	42	56	35	1·2 : 1·6 : 1
,, ,,	(2)	215	62	98	55	1·1 : 1·8 : 1
,, ,,	(3)	178	58	81	39	1·5 : 2·1 : 1
,, ,,	(4)	97	24	49	24	1·0 : 2·0 : 1
,, ,,	(5)	179	47	85	47	1·0 : 1·8 : 1
,, ,,	(6)	201	60	90	51	1·2 : 1·8 : 1
TOTAL		1,003	293	459	251	1·2 : 1·8 : 1
Expectation			*250·75*	*501·5*	*250·75*	

In one of these crosses (Punjab Type 9 × Punjab Type 25), a large number of the three kinds of F_2 plants were grown and the F_3 generation examined. All the fully bearded plants and those with tips bred true, while the half bearded plants again split up into fully bearded, half bearded and tipped plants in the ratio 1 : 2 : 1. The details relating to thirty-one of these cultures are given in the following table :—

TABLE II.

The F_3 generation of a cross between bearded and tipped parents.

Plant No	Bearding in F_2 parent	No. of plants in F_3	Bearding in the F_3 Generation			Ratio
			Fully bearded	Intermediate	Tipped	
10	Fully bearded	77	77	...	...	
31	do.	90	90	...	...	
218	do.	77	77	...	...	
233	do.	71	71	...	...	
319	do.	81	81	...	...	
459	do.	74	74	...	...	
470	do.	122	122	...	...	
499	do.	87	87	...	...	
	Carried over	679	679	...	...	

TABLE II.—(*contd*).

Table F_3 generation of a cross between bearded and tipped parents.

Plant No.	Bearding in F_2 parent	No. of plants in F_3	Bearding in the F_3 Generation			Ratio
			Fully bearded	Intermediate	Tipped	
	Brought forward	679	679	...	...	
611	Fully bearded	139	139	...	...	
649	do.	122	122	...	...	
924	do.	132	132	...	...	
65	Tipped	75	...	...	75	
138	do.	99	...	...	99	
509	do.	102	...	...	102	
566	do.	115	...	...	115	
582	do.	91	...	...	91	
787	do.	96	...	...	96	
853	do.	91	...	...	94	
940	do.	88	..	...	88	
1004	do.	113	...	..	113	
1026	do.	91	...	...	94	
1	Intermediate	60	16	26	18	
4	do.	49	15	27	7	
30	do.	93	21	49	23	
75	do.	86	19	41	26	
79	do.	62	14	27	21	
184	do.	63	18	33	12	
317	do.	83	17	43	23	
368	do.	70	15	31	24	
401	do.	90	29	38	23	
468	do.	77	19	42	16	
481	do.	66	15	34	17	
507	do.	70	17	35	18	
623	do.	51	12	28	11	
760*	do.	62	18	27	17	
803	do.	66	12	39	15	
818	do.	80	17	46	17	
863	do.	55	16	23	16	
911	do.	89	20	46	23	
973	do.	80	20	44	16	
990	do.	67	14	38	15	
	TOTAL	1,419	344	717	358	·96 : 2 : 1
	Expectation		*354·75*	*709·5*	*354·75*	

Bearded × Beardless. The crosses between fully bearded and absolutely beardless parents, in which the F_1 generation was almost beardless, will now be considered. This was observed in the pure line cross between Pusa 22 (bearded) and A 88 (entirely beardless). The F_1, at first sight, seemed beardless but on close examination very short tips could be distinguished. In the F_2, a series of forms was produced which could be grouped with some difficulty into fully bearded, nearly fully bearded, half bearded, long tips, short tips, and beardless (Plate II). If all the variously bearded and tipped plants are classed as bearded, which would seem to be the best method, the ratio bearded to beardless obtained is 15 : 1 and the presence of two factors is indicated. The details relating to the F_2 generation are given in Table III.

TABLE III.

The F_2 generation of crosses between bearded and quite beardless parents.

Cross		No. of plants	Bearding in the F_2 Generation: Fully bearded	Almost fully bearded	Half bearded	Tips of varying length	Beardless
A 88 ♀ × Pusa 22 ♂	(1)	168	12	11	19	117	9
,, ,,	(2)	247	18	11	28	173	17
,, ,,	(3)	258	16	20	31	174	17
Pusa 22 ♀ × A 88 ♂	(4)	117	5	11	17	76	8
,, ,,	(5)	196	10	12	29	133	12
TOTAL	...	986	61	65	124	673	63
Ratio	...		1	1	2	10·7	1

It was suggested, in the previous paper, that the simplest explanation of these results appeared to be that, in the bearded parent, two factors are present, one capable of producing short awns or tips only, the other, when added to this, resulting in fully bearded plants. On the presence and absence hypothesis, the results of the various crosses would be represented as follows. Assuming the fully bearded parent contains two factors B and T (B representing the long and T the short factor), the tipped plants contain only one factor T, while the absolutely beardless plants contain neither, then—

1. Fully bearded wheats would be represented by BBTT.
2. Plants with tips only would be represented by bbTT.
3. Absolutely beardless plants would be represented by bbtt.
4. The cross P 22 × A 88 between a fully bearded parent (BBTT) and a beardless (bbtt) would give BbTt in the F_1, while the F_2 would be represented by the formula :—

BBTT + 4BbTt + 2BbTT + 2BBTt + bbTT + 2bbTt + BBtt + 2 Bbtt + bbtt.

To place the matter beyond doubt and to isolate if possible the two factors, the cross was continued to the F_4 generation.

In the F_3, as many as possible of one of the sets of F_2 plants were grown. The second set in Table III was selected and out of the whole 247 plants, 230 were found to have ripened sufficient seed for sowing. Of the seventeen remaining plants, one was described as fully bearded, two as half bearded while fourteen were tipped. Four distinct classes of plants gave uniform cultures in the F_3—fully bearded like P 22, quite beardless like A 88, plants with long tips and plants with short tips. These two classes of tipped plants

proved to be the two constituent factors of the fully bearded character. Some practice is required in distinguishing them. In the long tipped plants (Plate VI), the beards are only found at the tip of the ear where one is often much longer than the rest. In the short tipped plants (Plate VII), the beards are more or less the same length and are generally uniformly distributed over the upper two-thirds of the ear. If these two sets of tips are examined closely, it will be found that the short factor serves to distribute the foundations of the bearding over the whole ear, while the long factor acts as an intensifier. Besides the four sets of cultures which bred true in the F_3, five different kinds of splitting could be distinguished. Fifty-four cultures resembled the F_2 and gave all stages from bearded to beardless in the proportion of about 15 bearded to 1 beardless. Out of a total of 2,540 plants, there were 174 fully bearded and 159 quite beardless. One set of cultures, 53 in number, split into three well defined classes—fully bearded, half bearded and long tips in the proportion 491 : 974 : 467, thus indicating the ratio of 1 : 2 : 1. There was a corresponding group of 22 cultures which split into three groups—long tips, intermediate and beardless in the proportion of 292 : 586 : 233 which also indicates the ratio of 1 : 2 : 1. There were also two similar series of splittings, in which the short-tipped factor was concerned, in both of which the 1 : 2 : 1 ratio was apparent. The first of these between fully bearded and short tips occurred in 40 cultures in which the proportion of fully bearded, nearly bearded, short tips was 516 : 1007 : 494. The second, between short tips and beardless, was represented by 24 cultures in which there were 246 short tips, 551 intermediates and 261 beardless. The last four of these series are illustrated in Plate III. The intermediates between long tips and beardless and between short tips and beardless can be distinguished. In the former, the long terminal tip of the long tipped factor occurs about half-developed. In the F_1 between short tips and beardless, the beards almost entirely disappear and can only be distinguished after some practice.

When the above tables are compared with Table III, it will be seen that the rough classification of the F_2 into 18 fully bearded, 11 almost fully bearded, 28 half bearded, 173 with tips of varying length and 17 beardless was not quite accurate. The ears of the F_2 were examined at harvest time when it is exceedingly difficult to prevent damage to the awns in the dry heat which prevails at Pusa at this period. Of the seventeen plants described as beardless in 1912, twelve gave rise to uniformly beardless offspring while five split from short tips to beardless. Before the plants were examined in 1912, the short tips of these plants must have suffered considerable damage. Eight-

Table V.

The F_3 generation of a cross between a fully bearded and a quite beardless plant.

Plant no. in F_2, 1912	Bearding in F_2	No. of plants in F_3	Bearding in the F Generation, 1913								
			Fully bearded BBTT	Minute tips BbTt	Half bearded BBTt	Nearly bearded BbTT	Long tips BBtt	Minute tips Bbtt	Short tips bbTT	Minute tips bbTt	Beardless bbtt
4	Tips	68	4	...	...	...	...	...	...	...	3
5	do.	39	2	...	...	...	...	...	...	...	2
8	do.	39	3	...	...	...	...	...	...	...	1
13	do.	55	4	...	...	...	...	...	...	...	7
17	do.	21	5	...	...	...	...	...	...	...	1
20	do.	42	3	...	...	...	...	...	...	...	4
25	do.	?	3	...	...	...	...	...	...	...	1
26	do.	54	3	...	...	...	...	...	...	...	3
27	do.	82	3	...	...	...	...	...	...	...	1
30	do.	25	3	...	...	...	...	...	...	...	1
32	do.	28	3	...	...	...	...	...	...	...	1
35	do.	16	0	...	...	...	...	...	...	...	1
40	do.	55	2	...	...	...	...	...	...	...	1
43	do.	50	3	...	...	...	...	...	...	...	3
49	do.	49	2	...	...	...	...	...	...	...	2
56	do.	31	1	...	...	...	...	...	...	...	0
57	do.	25	0	...	...	...	...	...	...	...	2
73	do.	46	3	...	...	...	...	...	...	...	3
74	do.	51	2	...	...	...	...	...	...	...	6
86	do.	47	3	...	...	...	...	...	...	...	0
87	do.	50	2	...	...	...	...	...	...	...	3
91	do.	65	9	...	...	...	...	...	...	...	3
99	do.	57	5	...	...	...	...	...	...	...	3
108	do.	52	4	...	...	...	...	...	...	...	3
111	do.	112	8	...	...	...	...	...	...	...	4
113	do.	24	0	...	...	...	...	...	...	...	2
119	do.	52	5	...	...	...	...	...	...	...	3
121	do.	66	2	...	...	...	...	...	...	...	4
131	do.	57	4	...	...	...	...	...	...	...	4
138	do.	54	0	...	...	...	...	...	...	...	3
139	do.	38	0	...	...	...	...	...	...	...	1
153	do.	53	7	...	...	...	...	...	...	...	5
156	do.	42	3	...	...	...	...	...	...	...	5
159	do.	58	7	...	...	...	...	...	...	...	4
160	do.	67	3	...	...	...	...	...	...	...	4
162	do.	75	5	...	...	...	...	...	...	...	5
170	do.	74	5	...	...	...	...	...	...	...	3
175	do.	65	4	...	...	...	...	...	...	...	6
182	do.	58	3	...	...	...	...	...	...	...	4
189	do.	51	3	...	...	...	...	...	...	...	5
190	do.	78	3	...	...	...	...	...	...	...	6
193	do.	54	2	...	...	...	...	...	...	...	3
195	do.	71	7	...	...	...	...	...	...	...	3
197	do.	67	4	...	...	...	...	...	...	...	3
200	do.	61	4	...	...	...	...	...	...	...	5
204	do.	26	2	...	...	...	...	...	...	...	2
205	do.	?	1	...	...	...	...	...	...	...	2
210	do.	46	6	...	...	...	...	...	...	...	7
212	do.	?	1	...	...	...	...	...	...	...	2
217	do.	23	2	...	...	...	...	...	...	...	1
233	do.	25	2	...	...	...	...	...	...	...	1
234	do.	82	3	...	...	...	...	...	...	...	4
237	do.	56	4	...	...	...	...	...	...	...	4
246	do.	58	7	...	...	...	...	...	...	...	4
	Total	2,540	174	...	...	...	...	...	...	...	159
(Omitting nos. 25, 205 & 212)											
	Expectation	*2,540*	*158·8*								*158·8*

Table VI.

The F_3 generation of a cross between a fully bearded and a quite beardless plant.

Plant no. in F_2, 1912	Bearding in F_2	No. of plants in F_3	Bearding in the F_3 Generation, 1913: Fully bearded BBTT	Minute tips BbTt	Half bearded BBTt	Nearly bearded BbTT	Long tips BBtt	Minute tips Bbtt	Short tips bbTT	Minute tips bbTt	Beardless bbtt
11	Intermediate	21	6	...	...	10	...	...	5	...	...
16		36	8	...	...	21	...	...	7	...	...
21	do.	81	25	...	...	38	...	...	18	...	...
23	do.	59	16	...	...	28	...	...	15	...	...
46	do.	54	12	...	...	27	...	..	15	...	...
51	do.	85	27	...	...	36	...	...	22	...	...
54	do.	81	20	...	...	43	...	...	18	..	...
76	do.	56	11	..	...	34	...	...	11	...	..
80	do.	59	19	...	...	29	...	...	11	..	...
85	do.	76	22	...	...	36	...	...	18	...	...
90	do.	63	14	...	...	34	...	...	15	...	...
101	do.	72	19	...	...	35	...	...	18	...	...
106	do.	71	12	...	...	39	...	...	20	...	...
114	do.	30	4	...	...	17	...	...	9	...	...
115	do.	61	16	...	...	35	...	...	10	...	...
118	do.	60	14	...	...	31	...	...	15	...	...
126	do.	28	5	...	...	13	...	...	10	...	...
152	do.	29	4	...	...	17	...	...	8	...	...
158	do.	55	17	...	...	22	...	...	16	...	...
168	do.	71	20	...	...	34	...	...	17	...	...
173	do.	67	17	...	...	35	...	...	15	...	...
174	do.	90	15	...	...	46	..	..	29	...	...
181	do.	58	20	...	...	26	...	...	12	...	...
185	do.	55	17	...	...	22	...	...	16	...	...
187	do.	49	12	...	...	25	...	...	12	...	...
192	do.	69	14	...	...	42	...	...	13	...	...
201	do.	80	17	...	...	44	...	...	19	...	...
203	do.	55	8	...	...	32	...	...	15	...	...
207	do.	59	21	...	...	27	...	...	11	...	...
213	do.	48	13	...	...	22	..	...	13	...	...
221	do.	86	29	...	...	35	...	...	22	...	...
235	do.	66	23	...	...	30	..	...	13	...	...
236	do.	30	3	...	...	17	..	...	10	...	...
240	do.	57	16	...	...	25	...	...	16	...	...
96	do.	27	11	...	...	?	...	...	?	...	...
146	do.	44	11	...	...	?	...	...	?	...	...
172	do.	36	8	...	...	?	...	...	?	...	...
208	do.	32	7	...	...	?	...	...	?	...	...
216	do.	60	16	..	...	?	...	...	?	...	...
231	do.	54	18	...	...	?	...	...	?	...	...
245	do.	55	14	...	...	?	...	...	?	...	...
	Total	2,017	516	...	...	1,007	...	...	494	...	...
(Omitting nos. 96, 146, 172, 208, 216, 231, 245)											
Expectation		*2,017*	*504·2*			*1009·5*			*504·2*		
7	Tips	25	...	...	...	...	...	...	4	15	6
36	do.	57	...	...	...	...	...	...	12	33	12
41	Beardless	18	...	...	...	...	...	...	4	7	7
53	Tips	56	...	..	...	...	...	...	13	31	12
62	do.	29	..	...	...	...	...	...	5	14	10
63	do.	45	...		...	...	...	...	9	24	12
72	do.	33	...	...	...	...	...	...	9	17	7
88	do.	58	...	...	...	...	...	..	12	35	11
105	Beardless	79	...	...	...	...	...	...	16	43	20
109	Tips	62	...	...	...	...	...	...	13	36	13
125	do.	45	...	...	...	...	..	..	10	21	14
127	do.	31	...	..	...	...	...	...	8	18	5
128	Beardless	29	...	...	...	...	...	...	4	20	5
136	Tips	49	...	...	...	...	...	...	10	24	15
145	Beardless	63	...	...	...	...	...	...	14	28	21
151	Tips	42	...	...	...	...	...	...	8	24	10
157	do.	67	...	...	...	...	...	...	12	37	18
169	do.	45	...	...	...	...	...	...	11	21	13
178	do.	25	...	...	...	...	...	..	6	13	6
199	do.	42	...	...	...	...	...	...	11	20	11
209	do.	63	...	...	...	...	...	...	26	25	12
224	Beardless	22	...	...	...	...	...	...	9	11	2
227	Tips	22	...	...	...	...	...	...	6	10	6
239	do.	51	...	..	...	...	...	..	14	24	13
	Total	1,058	...	...	...	...	...	...	246	551	261
	Expectation	*1,058*							*264·5*	*529*	*264·5*

Table VII.

The F_3 generation of a cross between a fully bearded and a quite beardless plant.

Plant no. in F_2, 1912	Bearding in F_2	No. of plants in F_3	Bearding in the F_3 Generation, 1913								
			Fully bearded BB TT	Minute tips BbTt	Half bearded BBTt	Nearly bearded BbTT	Long tips BBtt	Minute tips Bbtt	Short tips bbTT	Minute tips bbTt	Beardless bbtt
1	Intermediate	61	16	...	30	...	15	...	...	...	...
9	do.	51	10	...	28	...	13	...	...	...	...
22	do.	74	20	...	34	..	20	...	...	...	...
28	do.	68	20	...	32	...	16	...	..	...	...
31	do.	24	4	...	13	...	7	...	...	...	...
33	do.	56	13	...	30	...	13	...	...	...	...
38	do.	58	15	...	29	...	14	...	...	...	...
47	do.	59	10	...	36	...	13	...	...	...	...
48	do.	75	15	...	42	...	18	...	...	..	...
52	do.	24	7	...	15	...	2	...	...	...	...
58	do.	91	31	...	43	...	17	...	...	...	...
64	do.	59	15	...	27	...	17	...	...	...	...
65	do.	64	19	...	30	...	15	...	...	...	...
66	do.	75	15	...	42	...	18	...	...	...	...
67	do.	62	14	...	33	...	15	...	...	...	...
69	do.	46	13	...	27	...	6	...	...	...	...
75	do.	59	13	...	29	...	17	...	..	...	...
78	do.	70	15	...	37	...	18	...	...	.	...
89	do.	57	18	...	27	...	12	..	...	...	...
95	do.	58	15	...	28	...	15	...	...	...	...
100	do.	53	13	...	25	...	15	...	..	...	...
129	do.	69	18	...	31	...	20	...	...	...	...
154	do.	48	11	...	25	...	12	...	...	..	...
176	do.	69	13	...	37	...	19	...	...	...	...
180	do.	65	17	...	34	...	15	...	...	...	...
183	do.	74	19	..	39	...	16	...	...	...	...
188	do.	36	6	...	20	...	10	...	...	...	...
218	do.	66	27	...	26	...	13	...	...	...	...
219	do.	72	20	...	36	...	16	...	...	..	...
220	do.	60	18	...	30	...	12	...	...	...	...
225	do.	69	20	...	34	...	15	..	...	..	...
229	do.	61	11	...	25	...	25	...	...	...	...
	TOTAL	1,934	491	...	974	...	469	...	...	..	...
	Expectation	*1,934*	*484·5*		*979*		*484·5*				
19	Tips	31	...	...	...	...	11	15	...	...	5
29	do.	52	...	...	...	...	17	25	...	...	10
50	do.	78	...	...	...	...	24	40	...	...	14
77	do.	33	...	...	...	...	8	17	...	...	8
79	do.	64	...	...	...	...	17	35	...	...	12
82	do.	36	...	...	...	...	11	17	...	..	8
92	do.	86	..	...	...	...	27	41	...	...	18
97	do.	52	...	...	...	...	10	28	...	..	14
98	do.	39	...	...	..	...	9	22	...	..	8
104	do.	49	...	...	...	...	9	28	...	...	12
117	do.	44	...	...	...	...	12	27	...	...	5
123	do.	37	...	...	..	...	9	24	...	...	4
140	do.	68	...	...	...	...	16	35	...	...	17
163	do.	59	...	...	...	...	18	30	...	...	11
164	do.	36	...	...	...	...	8	21	..	...	7
166	do.	46	...	...	...	...	12	24	...	...	10
196	do.	45	...	...	...	...	9	25	...	..	11
211	do.	53	...	...	...	...	15	24	...	...	14
215	do.	39	...	...	...	...	7	26	...	...	6
223	do.	49	...	...	...	..	15	20	...	...	14
238	do.	62	...	...	...	...	14	34	...	...	14
243	do.	53	...	...	...	...	14	28	...	...	11
	TOTAL	1,111	...	...	...	...	292	586	...	...	233
	Expectation	*1,111*					*277·7*	*555·5*			*277·7*

Table IX.

The F_4 generation of a cross between a fully bearded and a quite beardless plant.

Plant no. in F_3, 1913	Bearding in F_3	No. of plants in F_4	Bearding in the F_4 Generation, 1914: Fully bearded BBTT	Minute tips BbTt	Half bearded BBTt	Nearly bearded BbTT	Long tips BBtt	Minute tips Bbtt	Short tips bbTT	Minute tips bbTt	Beardless bbtt
120—1	Beardless	89	...	...	...	...	...	...	...	...	89
2	do.	69	...	...	...	...	...	...	...	...	69
3	do.	74	...	...	...	...	...	...	...	...	74
13	do.	75	...	...	...	...	...	...	...	...	75
19	do.	74	...	...	...	...	...	...	...	...	74
	Total	381	...	...	...	...	...	...	...	...	381
	Expectation	*381*									*381*
122—15	Beardless	57	...	...	...	...	...	...	...	...	57
28	do.	77	...	...	...	...	...	...	...	...	77
34	do.	72	...	...	...	...	...	...	...	...	72
35	do.	94	...	...	...	...	...	...	...	...	94
29	do.	86	...	...	...	...	...	...	...	...	86
60	do.	95	...	...	...	...	...	...	...	...	95
	Total	481	...	...	...	...	...	...	...	...	481
	Expectation	*481*									*481*
209—29	bbTT	81	...	...	...	...	...	...	81	...	...
41	do.	88	...	...	...	...	...	...	88	...	...
56	do.	58	...	...	...	...	...	...	58	...	...
9	bbTt	89	...	...	...	...	...	...	27	41	21
52	do.	68	...	...	...	...	...	...	21	28	18
53	do.	43	...	...	...	...	...	...	12	18	13
43	bbtt	79	...	...	...	...	...	...	...	...	79
47	do.	70	...	...	...	...	...	...	...	...	70
49	do.	61	...	...	...	...	...	...	...	...	61
106—2	bbTT	90	...	...	...	...	...	...	90	...	...
5	do.	85	...	...	...	...	...	...	85	...	...
12	do.	91	...	...	...	...	...	...	91	...	...
42	do.	74	...	...	...	...	...	...	74	...	...
44	do.	76	...	...	...	...	...	...	76	...	...
47	do.	79	...	...	...	...	...	...	79	...	...
171—1	bbTT	79	...	...	...	...	...	...	79	...	...
4	do.	64	...	...	...	...	...	...	64	...	...
12	do.	77	...	...	...	...	...	...	77	...	...
13	do.	77	...	...	...	...	...	...	77	...	...
33	do.	91	...	...	...	...	...	...	91	...	...
53	do.	77	...	...	...	...	...	...	77	...	...
222—6	bbTT	71	...	...	...	...	...	...	71	...	...
8	do.	58	...	...	...	...	...	...	58	...	...
14	do.	60	...	...	...	...	...	...	60	...	...

Table X.

The F_4 generation of a cross between a fully bearded and a quite beardless plant.

Plant no. in F_3, 1913	Bearding in F_3	No. of plants in F_4	Bearding in the F_4 Generation, 1914								
			Fully bearded BBTT	Minute tips BbTt	Half bearded BBTt	Nearly bearded BbTT	Long tips BBtt	Minute tips Bbtt	Short tips bbTT	Minute tips bbTt	Beardless bbtt
243—8	BBtt	48	...	...	...	...	48	...	...	...	...
14	do.	61	...	...	...	...	61	...	...	...	...
21	do.	59	...	...	...	...	59	...	...	...	...
38	Bbtt	51	...	...	...	...	11	26	...	...	14
53	do.	48	...	...	...	...	11	26	...	...	11
54	do.	71	...	...	...	...	22	34	...	...	15
24	bbtt	71	...	...	...	...	...	...	...	...	71
44	do.	60	Two stray plants, possibly natural crosses				...	...	...	...	58
14—27	BBtt	93	...	...	...	...	93	...	...	...	...
32	do.	97	...	...	...	...	97	...	...	...	...
34	do.	95	...	...	...	...	95	...	...	...	...
53	do.	86	...	...	...	...	86	...	...	...	...
15—23	BBtt	68	...	...	...	...	68	...	...	...	...
51	do.	73	...	...	...	...	73	...	...	...	...
55	do.	60	...	...	...	...	60	...	...	...	...
93—18	BBtt	86	...	...	...	...	86	...	...	...	...
29	do.	89	...	...	...	...	89	...	...	...	...
34	do.	82	...	...	...	...	82	...	...	...	...
42	do.	52	...	...	...	...	52	...	...	...	...
191—4	BBtt	84	...	...	...	...	84	...	...	...	...
20	do.	116	...	...	...	...	116	...	...	...	...
31	do.	53	...	...	...	...	53	...	...	...	...
33	do.	92	...	...	...	...	92	...	...	...	...
34	do.	97	...	...	...	...	97	...	...	...	...
231—2	BBtt	50	...	...	...	...	50	...	...	...	...
14	do.	59	...	...	...	...	59	...	...	...	...
18	do.	65	...	...	...	...	65	...	...	...	...
24	do.	37	...	...	...	...	37	...	...	...	...
85—44	BBTT	59	59	...	...	...	...	...	...	...	...
51	do.	57	57	...	...	...	...	...	...	...	...
53	do.	86	86	...	...	...	...	...	...	...	...
30	BBTt	80	26	...	36	...	18	...	...	...	...
36	do.	81	16	...	47	...	18	...	...	...	...
55	do.	100	26	...	41	...	33	...	...	...	...
20	BBtt	72	...	...	...	...	72	...	...	...	...

Table XI.

The F_4 generation of a cross between a fully bearded and a quite beardless plant.

Plant no. in F_3, 1913	Bearding in F_3	No. of plants in F_4	Bearding in the F_4 generation, 1914								
			Fully bearded BBTT	Minute tips BbTt	Half bearded BBTt	Nearly bearded BbTT	Long tips BBtt	Minute tips Bbtt	Short tips bbTT	Minute tips bbTt	Beardless bbtt
126—9	BBTT	80	80	...	...	...	...	...	...	...	...
12	do.	86	86	...	...	...	...	...	...	...	...
16	do.	85	85	..	...	...	...	...	...	...	...
5	BbTT	62	15	...	..	32	...	...	15	...	..
11	do.	97	21	...	...	55	..	...	21	...	...
19	do.	112	31	...	...	63	...	...	18	...	...
1	bbTT	?	...	...	...	...	...	...	all	...	...
14	do.	104	...	...	...	...	..	...	104	...	...
27	do.	64	...	...	...	...	...	...	64	...	...
208—20	BBTT	60	60	...	...	...	...	..	...	...	...
21	do.	70	70	...	...	...	...	...	...	...	...
23	do.	82	82	...	...	...	...	...	...	...	...
14	BbTT	82	22	...	..	42	...	...	18	...	...
22	do.	92	16	...	...	53	...	...	23	...	...
25	do.	72	13	...	...	40	...	...	19	...	...
1	do.	94	25	...	...	48	...	...	21	...	...
12	do.	69	15	...	...	36	...	...	18	...	...
9	bbTT	61	...	...	...	...	...	...	61	...	..
16	do.	63	...	...	...	..	...	...	63	...	...
181—1	BBTT	35	35	...	...	...	...	...	...	...	...
15	do.	25	25	...	...	...	...	...	...	...	...
36	do.	82	82	...	...	...	...	..	...	...	...
51	do.	75	75	...	...	...	...	...	...	...	...
6	BbTT	54	14	...	...	27	...	...	13	...	...
31	do.	70	19	...	...	31	...	...	20	...	...
41	do.	62	20	...	...	24	...	...	18	...	...
23	bbTT	62	..	...	...	...	...	...	62	...	...
30	do.	64	...	...	...	...	...	...	64	...	...
48—39	BBTT	47	47	...	...	...	...	...	...	...	...
64	do.	75	75	...	...	...	...	...	...	...	...
68	do.	41	41	...	...	...	...	...	...	...	...
21	BBTt	70	19	...	36	...	15	...	...	...	...
77	do.	68	14	...	34	...	20	...	...	...	..
12	BBtt	68	...	...	...	...	68	...	...	...	...
27	do.	63	...	...	...	..	63	...	...	...	...
31	do.	68	...	...	...	...	68	...	...	...	...
64—25	BBTT	48	48	...	...	...	...	...	...	...	...
44	do.	58	58	...	...	...	...	...	...	...	..
57	do.	97	97	...	...	...	...	...	...	...	..
22	BBTt	94	27	...	53	...	14	...	...	...	...
33	do.	75	22	...	37	...	16	..	...	...	...
55	do.	95	24	...	46	..	25	...	...	...	...
19	BBtt	41	...	...	...	...	41	...	...	...	...
43	do.	43	...	...	...	...	43	...	...	...	...
176—11	BBTT	80	80	...	...	...	...	...	...	...	..
39	do.	58	58	...	..	...	...	...	...	...	...
10	BBTt	66	15	...	30	...	21	...	...	...	...
19	do.	64	15	...	38	...	11	...	...	...	...
54	do.	38	12	...	13	...	13	..	...	...	...
18	BBtt	57	...	...	...	...	57	...	...	...	...
34	do.	59	...	...	...	...	59	...	...	...	..
38	do.	66	...	...	...	...	66	...	...	...	...

een plants were described as fully bearded in the F_2. Of these, one was not sown, sixteen bred true and gave only fully bearded plants while one split from fully bearded to tips. Among the 196 intermediate cultures with beards of various lengths, only one gave results which were not expected. This was composed entirely of beardless plants, thereby proving that it had not been accurately described at harvest time.

The actual results of the examination of the F_3, compared with the theoretical numbers relating to the whole 247 F_2 plants, are set out in Table VIII. The discrepancies are due to the fact that seventeen plants were not grown, one fully bearded and sixteen tipped.

TABLE VIII.

Summary of the F_3 generation of a cross between a fully bearded and quite beardless plant.

	BBTT	BbTt	BbTT	BBTt	BBtt	Bbtt	bbTT	bbTt	bbtt
Actual	16	54	40	33	15	22	13	24	13
Theoretical	*15·5*	*61·6*	*30·8*	*30·8*	*15·4*	*30·8*	*15·4*	*30·8*	*15·4*

The various stages in bearding between the fully awned and beardless condition with the exception of plants like the F_1 which are shown in Plate II are illustrated in Plate III. On the left hand side, the stages between fully bearded and long tips and between long tips and beardless are represented. On the right, the corresponding stages between bearded and beardless, in which the short tipped factor is concerned, are shown. The gametic constitution of each form is given on Plate III.

The results of the third generation were confirmed by the behaviour of selected plants carried to the F_4. The long tips and short tips bred true as well as the bearded and beardless plants. The detailed results of this generation are set out in Tables IX to XI opposite.

The isolation of the two factors, which together produce the fully bearded character in wheats like Pusa 22, was followed by the detection of similar forms among the collection of varieties at Pusa. Several wheats with short awns breeding true had already been noticed and these were now carefully examined. Pusa 6 appeared to carry the long tipped factor while Pusa 7 seemed to have short tips (Plate V).

It was then decided to recombine the short and long tips which had been isolated from the F_4 of the cross P 22 × A 88 and also to cross Pusa 6 and Pusa 7. We should expect, in both cases, to obtain similar results in the F_1, namely, plants with minute tips represented by the formula BbTt. In the F_2, a series would be expected from fully bearded to beardless with bearded to beardless in the ratio of 15 : 1.

In the recombination of the bearding factors of P 22, the long tipped parent was numbered 243-21 while the short tips were obtained from 126-27 (Plate IV). The cross was made in February 1914 at Pusa and the seeds were at once despatched to the new Experiment Station at Quetta where they were spring sown. The F_1 plants ripened in June 1914 and the seeds for the F_2 were sown at Pusa the following October. In this way, a year was saved. The F_1 plants were almost beardless while the F_2 ranged from beardless to fully bearded. Fifty-nine plants were obtained of which four were beardless and four fully bearded. All stages in bearding were represented in the remainder.

In the case of the cross P 6 × P 7 the same procedure was adopted and the results obtained were similar. The F_1 was almost beardless while in the F_2, fully bearded, beardless and all stages of intermediates occurred. Two hundred and seven F_2 plants were raised of which 15 were fully bearded and 11 beardless. The combined results are set out in Table XII.

TABLE XII.

The F_2 generation between long tips and short tips.

CROSS	Total no. of plants	Bearded	Intermediates	Beardless	RATIO
243-21 × 126-27	59	4	51	4	13·75 : 1
Expectation	*0*	*3·7*		*3·7*	
Pusa 6 × Pusa 7	207	15	181	11	17·81 : 1
Expectation		*13*		*13*	

The results obtained in crossing long tips and short tips and the production of fully bearded plants in the F_2 breeding true, would explain the earlier observations of Rimpau and Spielmann on this point. If the tipped forms are regarded as beardless, a natural conclusion some years ago, it would be easy to get bearded forms in the second generation and so obtain quite unexpectedly an entirely new character.

Two other cases of a cross between a bearded and quite beardless parent were investigated. When Punjab Type 9, a bearded wheat, was crossed with

Pusa 4, an entirely beardless form, 610 plants were examined in the F_2. Of these, 39 were beardless and the remaining 571 were awned to varying degrees ranging from fully bearded to minute tips. The ratio bearded to beardless was therefore 14·6 : 1 indicating the existence of two factors in the bearded parent. Similar results were obtained in the F_2 between BXI 77, a fully bearded form, and Pusa 4. Among 576 F_2 plants, 43 were quite beardless, the remaining 533 carrying awns of various kinds from fully bearded to small tips. These numbers give a ratio of bearded to beardless of 13·4 : 1.

The isolation of the two constituents of the fully bearded character may prove of some practical value in India where there is, among the people in certain localities, a preference for awned wheats. The ryots consider that bearded wheats hold their grain better than beardless wheats and are also damaged by birds and wild pigs to a lesser extent. The disadvantages of awns, however, are considerable, particularly when it is desired to grow heavy crops. The greater resistance offered to the wind and the increased weight of the ear (caused by the deposition of dew and rain water among the awns) render bearded wheats very liable to lodge and so bring about a much greater loss of crop than is ever caused by birds, animals, or by the shedding of grain. By the selection of suitable types with short or long tips, it might be possible to meet the prejudices of the people while avoiding the main disadvantages of long awns.

During these experiments, it was observed that the development of the bearded or beardless character was not always uniform. If all the ears of a plant are examined, it is found that there is a considerable range in variation. In the case of cultures breeding true to long or short tips, this is particularly the case. The first formed and largest ears have the longest awns while those which are produced later have almost no awns. This point is illustrated in Plates VI and VII, in which all the ears of a long and short tipped plant are shown. In both cases, one or more of the ears are almost beardless. In like manner, there are similar differences between the average amount of bearding among the long and short tipped cultures taken as a whole. In some, the character is more developed than in others. This appears to be largely a matter of vigour. Well-grown cultures develop tips normally and there is no difficulty in deciding whether the tips are long or short. In weaker cultures (and in the last formed ears of any particular plant) the tips do not grow well and care is necessary to distinguish their nature. A similar state of things was observed in the beardless parent itself. The first formed and strongest ears of any particular plant show very minute tips while in the last formed these are absent (Plate VIII). Such variations as these between the ears of a single plant are being

constantly observed. They show how necessary it is in plant-breeding work that the crop should be grown to perfection so that each character attains its fullest expression.

In the actual conduct of the breeding work, two points of some importance were encountered which deserve mention. Observations on bearding are best made when the ears are still green and just before the chaff begins to change in colour. If a well developed ear is taken from each plant at this stage, the analysis of each culture can be made at once and the work completed before the ears ripen after which the danger of damage to the awns by high winds is considerable. The second point is concerned with the raising of complete cultures from any particular plant. Sown in the ground there is often a considerable loss of plants after sowing time caused by high temperatures. If such cultures, even when the grain is shrivelled, are first sown in boxes and then transplanted into the field in early November, no loss takes place. Plants raised in this manner are always healthier and better developed than those sown direct in the ordinary way.

II. Felted and Smooth Chaff.

In the previous paper, a detailed account was given of the inheritance of the felted character where two factors were involved. Several cases of simple felting were also described. When the pure line, known as Punjab Type 9, a form with densely felted chaff, was crossed with a wheat with smooth chaff, after an intermediate F_1, a series of forms from densely felted wheats, like the parent, to smooth was obtained in the second generation; the ratio felted to smooth being 15·2 : 1. An examination of the chaff of Punjab Type 9 under the microscope showed that two kinds of hairs were present—long silky hairs and much shorter ones. An analysis of the F_3 and subsequently of the F_2 generation resulted in the isolation of these two kinds of hairs and in the proof that each kind is inherited separately.

Among the crosses, felted by smooth, examined, two were of some interest. In the felted parents, only one class of short hairs was distinguished under the microscope and in both cases the 3 : 1 ratio was obtained in the F_2. The felted parents in these crosses were pure lines selected from common wheats and are described in the records as BXI 77 and Pusa 4. It appeared, from direct examination, that the hairs on both these wheats might be different and accordingly they have been crossed together and also with Punjab Type 9. If the felting factors in BXI 77 and Pusa 4 are different, a cross between these would give smooth progeny in the F_2. If they are different from the

short factor in Punjab Type 9, the ratio felted to smooth in the F_2 would be 63 : 1.

To investigate this matter the following crosses were made in 1913 :—

1. Pusa 4 × BXI 77.
2. Punjab Type 9 × Pusa 4.
3. Punjab Type 9 × BXI 77.

Pusa 4 × BXI 77. In the F_1, the felting appeared rather denser than that of either parent but, as the plants were particularly well-grown, the effect might be due to the full expression of the felted character. The seed of five of the F_1 plants was grown in 1914 and the progeny was examined in April last. The results are given in Table XIII.

TABLE XIII.

The F_2 generation of a cross between parents with simple felting.

	Total no. of plants	Felted	Smooth
(1)	134	134	0
(2)	271	271	0
(3)	254	254	0
(4)	305	305	0
(5)	256	256	0
TOTAL	1,220	1,220	0

The degree of felting in these 1220 F_2 plants was uniform and only one class of hairs was present. The results prove that the felting factors in the parents P 4 and BXI 77 are really identical. When examined in previous years, the hairs of these wheats seemed different. There are two reasons for this apparent difference. In the first place, P 4 is beardless and BXI 77 is bearded. The presence of the beards protects the chaff from rubbing and from loss of hairs due to this cause. In the second place, the development of the hairs depends on the season and the healthiness of the plant. On vigorous plants, the hairs appear longer and stronger than on weak individuals.

Punjab Type 9 × Pusa 4. In this case, the former parent carries two felting factors, the latter only one. The object of the cross was to determine whether or not the short factor of Punjab Type 9 is different from the simple hairs of Pusa 4. If they are different, three factors would be involved and the ratio felted : smooth in the F_2 would be 63 : 1. The F_1 plants were exceedingly well developed and the felting was very dense, much denser than in the case of Pusa 4 or BXI 77. In the F_2, no smooth individuals were obtained and the felting was not uniform. Five F_1 plants were grown for the F_2 and from these 1,385 individuals were obtained. All were felted and not a single

smooth plant was obtained. The felting in two of the five cultures was now examined in detail. The plants with felting like P 4 were picked out by eye and these were confirmed by comparing their chaff with that of P 4 under the microscope. The results are given in Table XIV.

TABLE XIV.

The F_2 generation of a cross between complex and simple felted parents.

	Total no. of plants	Simple felting	Complex felting
Punjab Type 9 × Pusa 4 (1)	202	35	167
,, ,, (5)	310	76	234
TOTAL	512	111	401
Expectation		*128*	*384*

The results indicate that the short factor in Punjab Type 9 is identical with that present in Pusa 4. There is some divergence from the theoretical but this was due to the material. In 1915, many of the cultures at Pusa including this cross were badly damaged by rust and bad weather before harvest.

Punjab Type 9 × BXI 77. As in the previous case, the former parent has densely felted chaff in which two factors are involved while, in the second parent, the felting is simple. The F_1 generation was not very robust and to the eye the felting appeared less dense than in the case of the F_1 of Punjab Type 9 × P 4. Five F_1 plants were grown on for the F_2 which produced 1,419 individuals all felted to varying degrees. No smooth plants were obtained. In two cultures, the felting was examined in detail and was found to range between that of the parents. The plants with felting like that of BXI 77 were picked out by eye and the diagnosis confirmed by examining the chaff under the microscope. The results are given in Table XV.

TABLE XV.

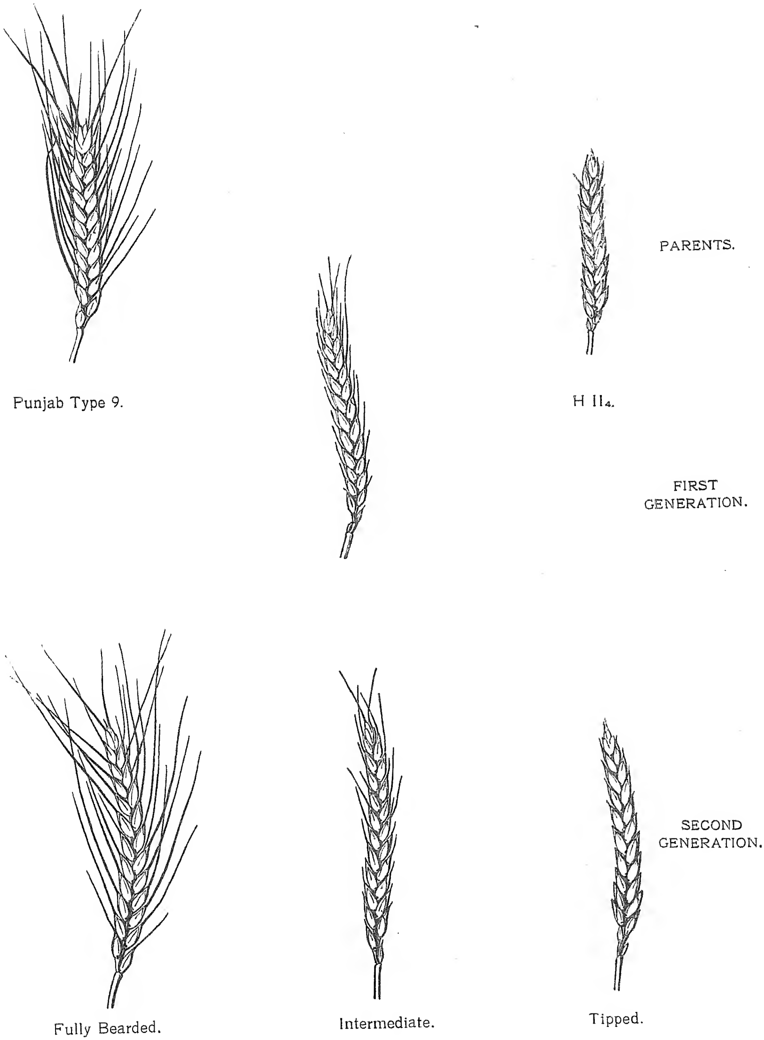
The F_2 generation between complex and simple felted parents.

	Total no. of plants	Simple felting	Complex felting
Punjab Type 9 × BXI 77 (3)	260	51	209
,, ,, (5)	274	81	193
TOTAL	534	132	402
Expectation		*133·5*	*400·5*

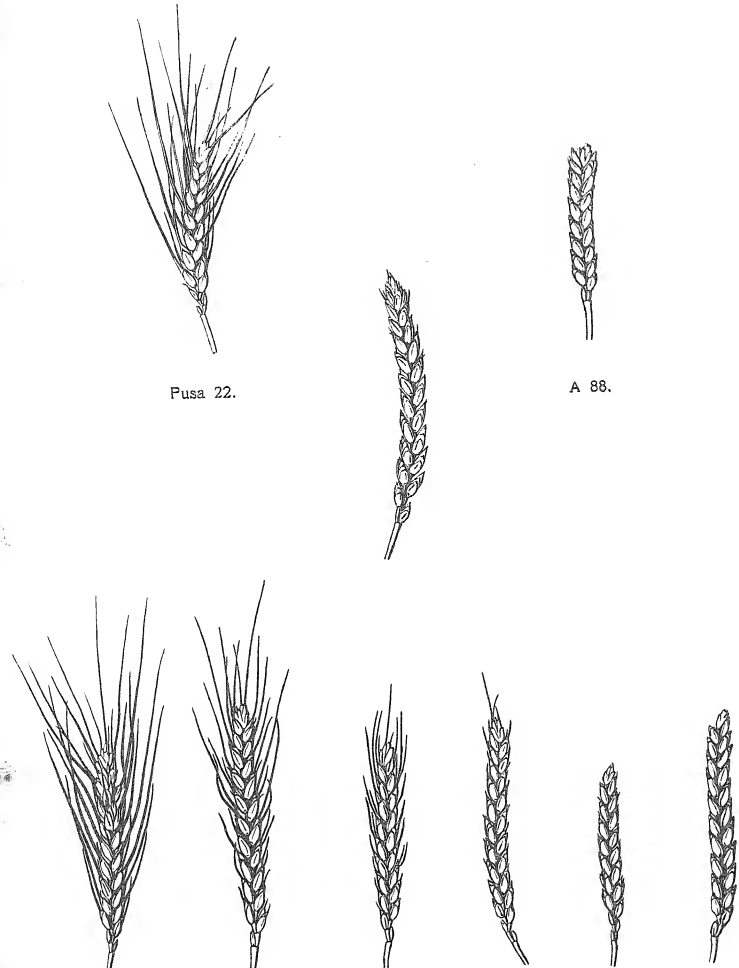
The results of the above three crosses prove that the felting in Pusa 4 is identical with that in BXI 77 and that the felting in both these cases is identical with the short factor in Punjab Type 9. From the economic point of view, this latter result was somewhat of a disappointment, as it was hoped to obtain some smooth individuals from this cross which might have proved of value. Felted chaff is a disadvantage in the moister wheat growing areas of India as the hairs condense dew and so add to the weight of the ear and increase the tendency to lodge. Further, the moisture tends to increase rust and other fungi on the chaff. There has been a natural elimination of felted wheats in Bihar and it is somewhat rare to find hairy chaff in the damper regions of the plains. In drier tracts like the Punjab, Central Provinces, Bombay and Baluchistan, on the other hand, felted chaff is much commoner.

QUETTA,
July 23, 1915.

PLATE I.



THE RESULT OF CROSSING BEARDED AND TIPPED WHEATS.



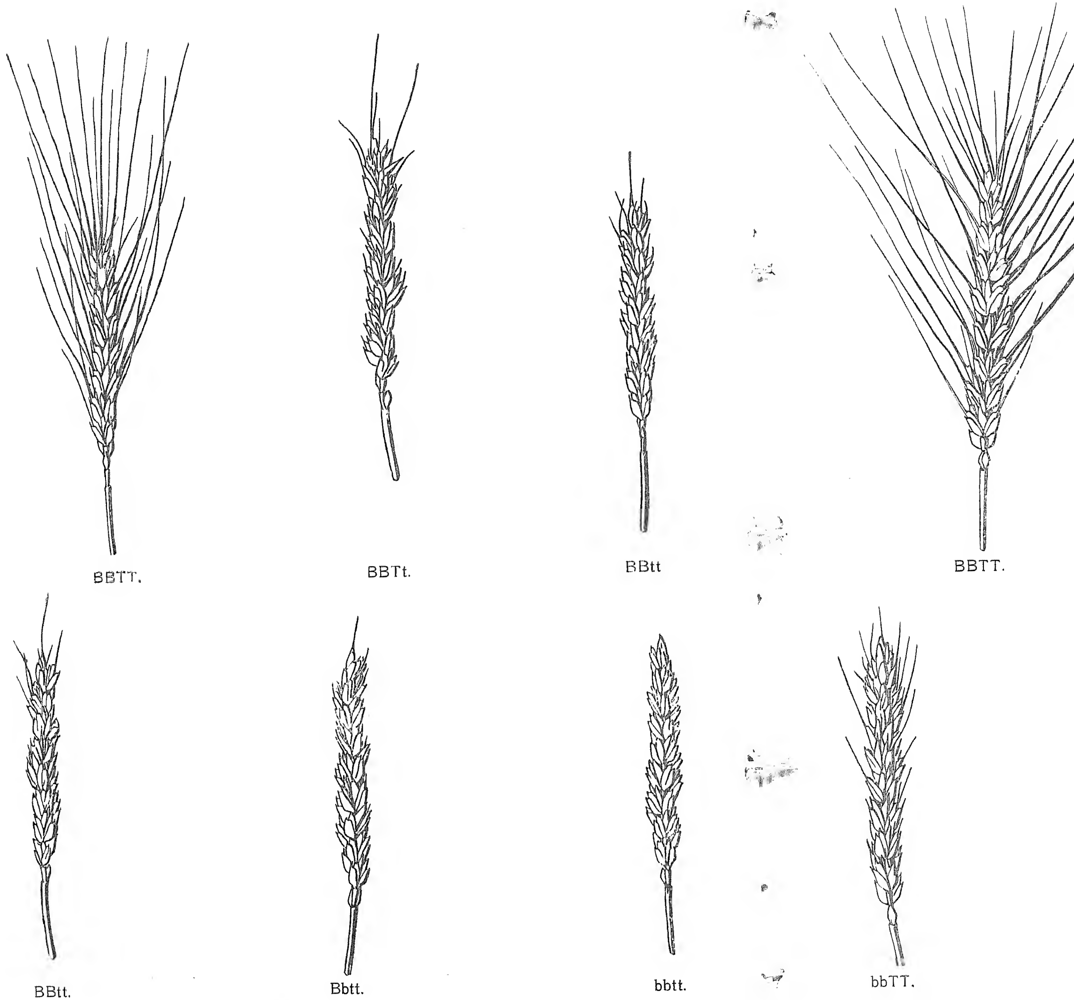
Pusa 22. A 88. PARENTS.

FIRST GENERATION.

SECOND GENERATION.

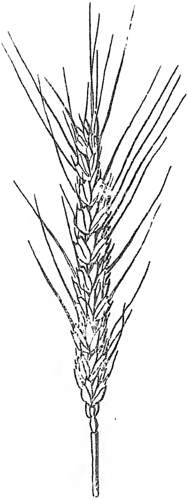
Fully bearded. Nearly fully bearded. Half bearded. Long tips. Short tips. Beardless.

THE RESULT OF CROSSING BEARDED AND BEARDLESS WHEATS.

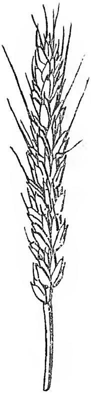


THE THIRD GENERATION OF THE CROSS P22 x A88.

PLATE III.



BbTT.

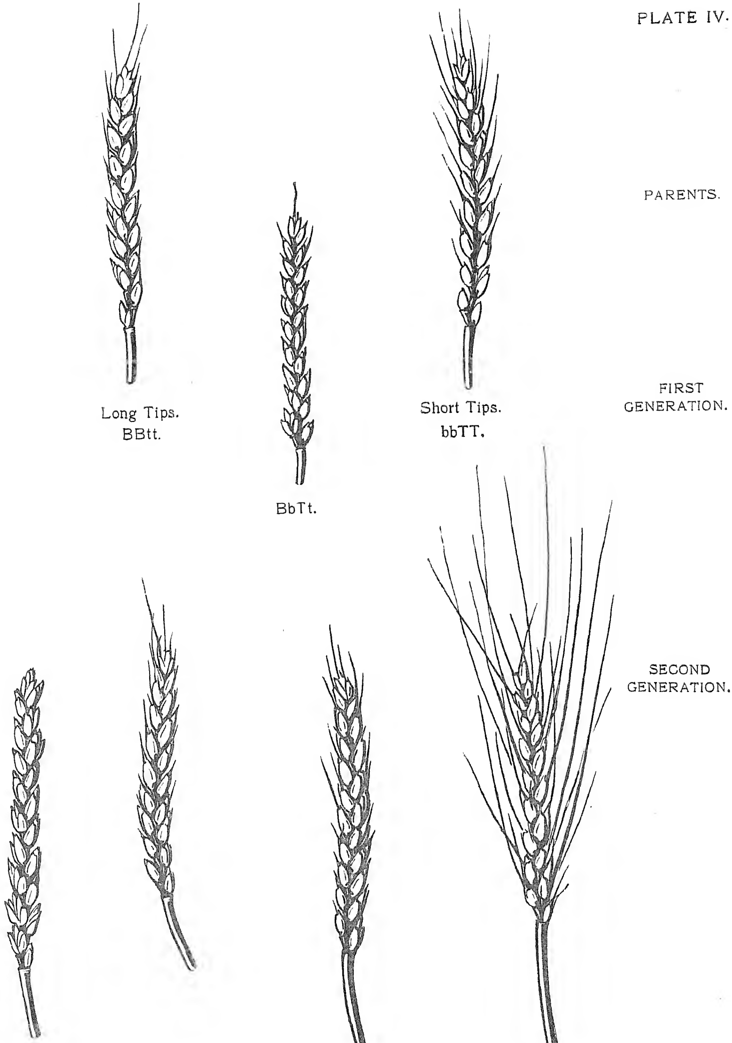


bbTT.

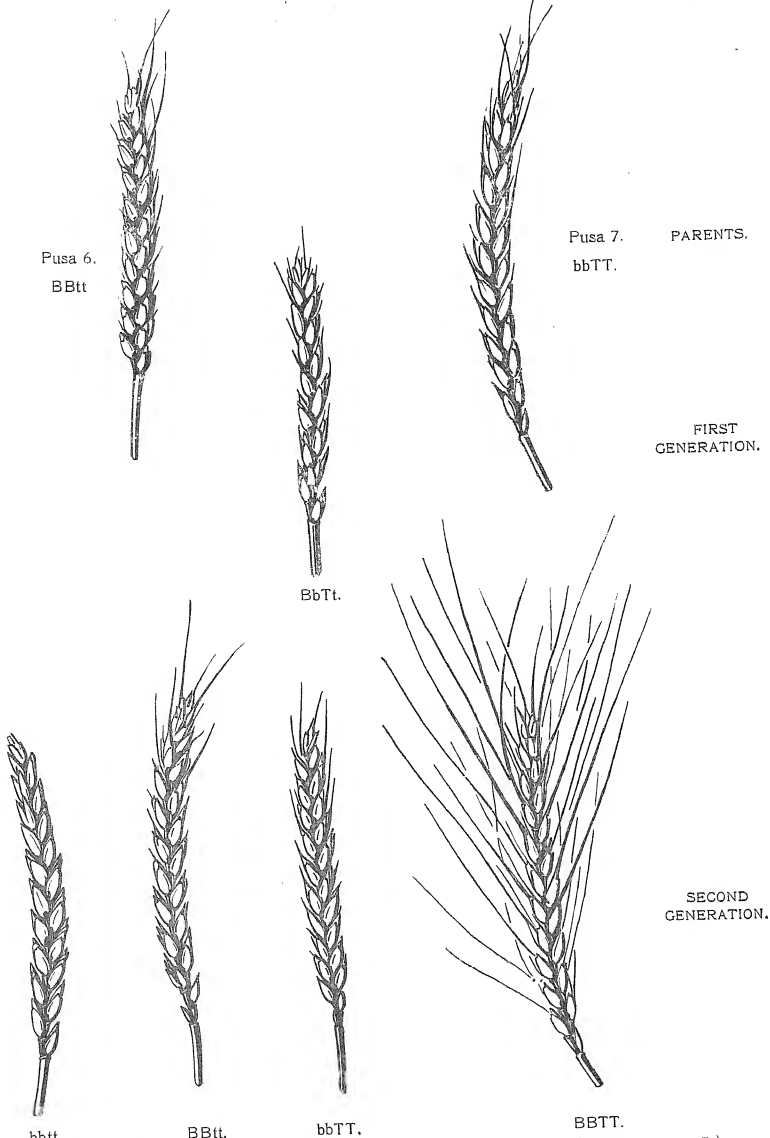
bbTt.

bbtt

PLATE IV.

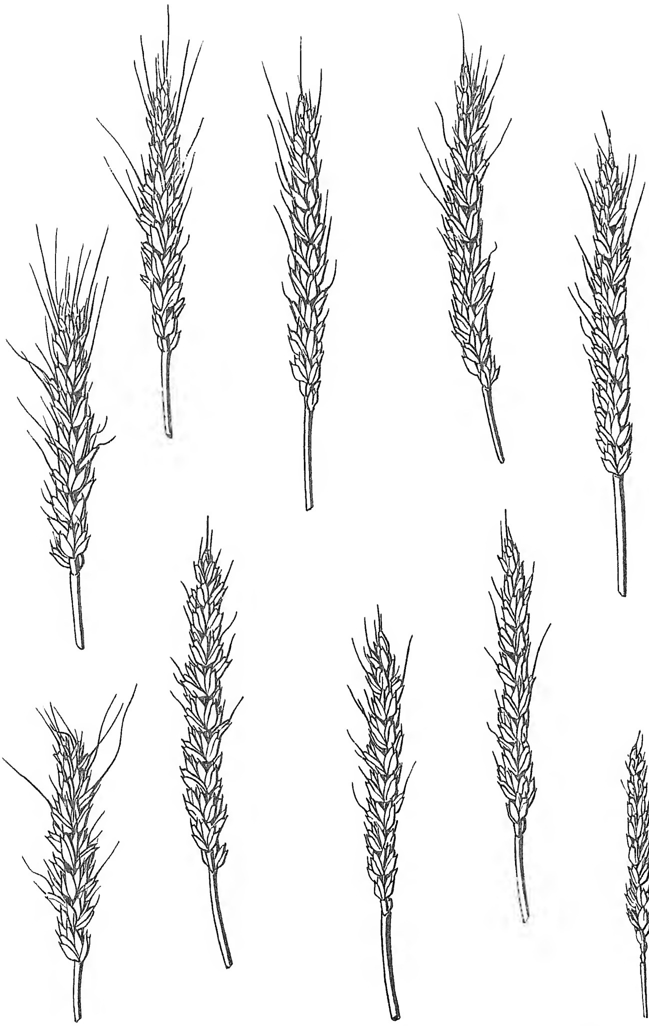


THE RECOMBINATION OF LONG TIPS AND SHORT TIPS.

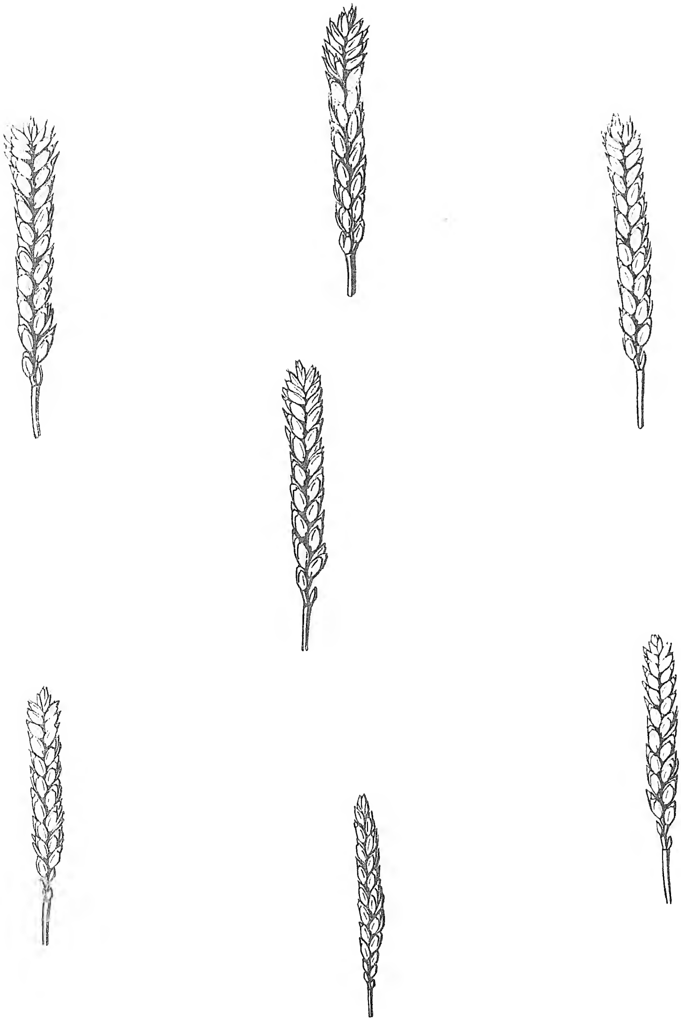


THE COMBINATION OF LONG TIPS AND SHORT TIPS (Pusa 6 x Pusa 7.)

VARIATION IN THE EARS OF A LONG TIPPED PLANT (BBtt).



VARIATION IN THE EARS OF A SHORT TIPPED PLANT (bbTT).



VARIATION IN THE EARS OF A PLANT OF A88 (bbtt).

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